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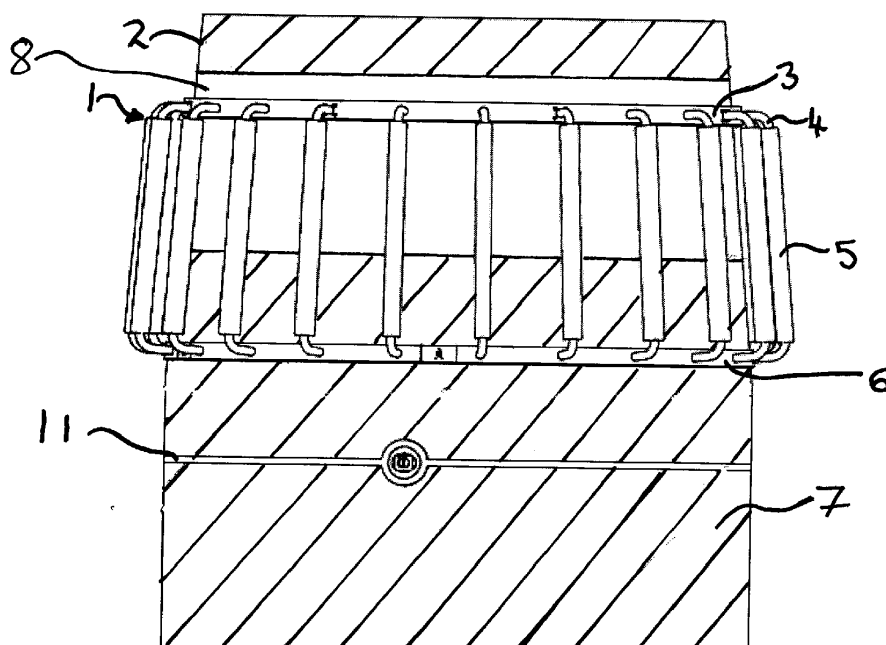
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(54) **ANODE STRUCTURE FOR AN OFFSHORE FOUNDATION, AND A METHOD OF REDUCING CORROSION IN AN OFFSHORE FOUNDATION**

(57) An anode structure (1) for connection to an offshore foundation. The body (2) of the offshore foundation has an anticorrosion coated surface region (7) and an exposed surface region (8) without an anticorrosion coating. The anode structure (1) comprises one or more anode elements (5) formed of a material having a more

negative electrode potential than the body of the offshore foundation, and an electrically conductive frame (3,4,6) for supporting the one or more anode elements (5). When the frame is attached to the offshore foundation (2), one or more electrical contact formations (9) provided on the frame contact the exposed surface region (8).

Fig. 1



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Description

TECHNICAL FIELD OF THE INVENTION

[0001] The present invention relates to an anode structure for providing cathodic protection from corrosion to the surface of an offshore foundation, and particularly foundations for offshore wind turbines. The present invention also relates to an offshore foundation, an assembly, and to a method for minimising corrosion of an offshore foundation using said anode structure.

BACKGROUND OF THE INVENTION

[0002] Offshore wind turbines are supported by foundations installed in the seabed. Such foundation structures are commonly monopiles. Other example foundations include jackets, suction buckets, floating foundations, gravity-based foundation and other foundation structures known to a person skilled in the art.

[0003] A monopile foundation comprises a body formed of a hollow tube that typically has a conical section. As such, the lower seabed-facing end is wider in diameter than the upper end facing the wind turbine tower. The monopile body forms a primary structure. In order to connect the wind turbine tower to a monopile, a transition piece is commonly used as an interface between the two. The transition piece is connected on a lower side thereof to the monopile and on an upper side thereof to the wind turbine tower. The transition piece can, if desired, be provided with additional constructions such as a work platform, a boat landing and other useful applications. These are considered to be secondary structures which are attached to the primary structure once it is installed.

[0004] The monopile is preferably installed by pile driving it into the seabed. It hence sits in the seawater and is thus susceptible to corrosion. In order to make a monopile corrosion-resistant, it is generally coated with corrosion-preventing paint to reduce corrosion. On top of this, it is also common to further provide an anode structure for providing galvanic corrosion protection. A common type of anode structure is called an anode cage, which comprises from a plurality of anode tubes arranged around the monopile on a ring-like frame which sits under water in use. The anodes are made of a less noble metal than the monopile's body and hence function as sacrificial anodes corroding instead of the monopile.

[0005] The monopile is for this purpose generally provided with suspension points which can only have limited dimensions. Suspension points with oversized dimensions are not desirable because they can affect the fatigue resistance of the monopile and form an obstacle during installation of the monopile. The anode cage thus preferably has to be arranged around the monopile with little clearance, and then electrically connected to the monopile using cables.

[0006] Remotely operated vehicles (ROVs) are often

used to connect the anode cage mechanically and electrically to the monopile because of the considerable hazards that divers would otherwise be exposed to.

[0007] During installation, the risk of damage to the anode cage or the monopile is considerable, especially when work has to be carried out in relatively severe weather. Alternatively, expensive equipment sits idle awaiting better weather. This is moreover time-consuming, among other reasons because the ROV has to perform a number of operations in succession, such as guiding the anode cage, mechanically connecting the anode cage, and then attaching the electric cable to the monopile for establishing the electrical connection. For each operation separate tools have to be retrieved and carried under water into the vicinity of the anode cage.

[0008] EP3483342 discloses an auxiliary device for positioning and securing an anode cage to a monopile. The device can be suspended from a hoisting means using a coupling and can be carried into the vicinity of the primary structure, i.e. the offshore wind turbine foundation. The support body of the auxiliary device comprises a number of remotely controlled tools for positioning the secondary structure, i.e. the anode cage, and forming the electrical and mechanical connections between the secondary and primary structures. For example, in the case of forming the electrical connection, EP3483342 uses an earthing cable connected to the anode cage at one end and to an earthing plate at the other. Once the device has located the anode cage in the desired position, a powder activated tool provided on the auxiliary device may then be triggered to drive the earthing plate into the monopile body under the force of a controlled explosion. As such, the earthing cable must have sufficient slack to accommodate the movement required by this direct fixing method. Once the electrical and mechanical connections between the secondary and primary structures have been realized, the auxiliary device can then be removed using the hoisting means. As such, the auxiliary device goes some way to addressing the technical problems of transporting, positioning and connecting the anode cage to a monopile without requiring ROVs or divers to perform such operations.

[0009] However, there are problems with the solution proposed by EP3483342. One issue, for example, is that the earthing cable providing the electrical connection between the anode cage and the monopile is prone to detach or simply snap over time due to the influence of ocean waves, current flow and tidal/swell. In such a scenario where there is a loss of electric connection between the anode cage and the monopile, the anti-corrosion effect of the sacrificial anode is lost. Furthermore, the continued inspection and maintenance of cables is expensive because it requires the use of ROVs or divers. Moreover, where divers are used for inspection and repair of cables, significant health and safety issues arise.

[0010] The present invention seeks to address the above problems associated with the prior art.

[0011] According to a first aspect of the present inven-

tion, there is provided an anode structure for connection to an offshore foundation having a body with a coated surface region and an exposed surface region without a coating, the anode structure comprising: one or more anode elements formed of a material having a more negative electrode potential than the body of the offshore foundation; an electrically conductive frame for supporting the one or more anode elements and for attachment to the body of the offshore foundation; wherein the electrically conductive frame comprises one or more electrical contact formations for contacting the exposed surface region when the frame is attached to the body.

[0012] In this way, the present invention thereby allows the anode structure to be electrically connected directly to the foundation body, without requiring separate connection cables. This provides for more straightforward installation and a more reliable earthing connection between the structures. The present invention also avoids or minimises the need to employ divers or ROVs devices to install the anode structure.

[0013] Preferably, the anode structure is an anode cage.

[0014] Preferably, the offshore foundation is a monopile.

[0015] Preferably, the coated surface region is coated with an anti-corrosion coating. More preferably, the anti-corrosion coating is an anti-corrosion paint.

[0016] Preferably, the one or more electrical contact formations comprise a plurality of electrical contact formations for contacting the exposed surface region.

[0017] Preferably, the electrical contact formations project inward from the electrically conductive frame. Preferably, the electrical contact formations are provided on an upper ring of the electrically conductive frame.

[0018] Preferably, the body of the offshore foundation comprises a conical section, and wherein the electrically conductive frame comprises a upper ring and a lower ring having a larger diameter than the upper ring, and where the upper and lower rings are sized for mating with the conical section of the body at a position for aligning the one or more electrical contact formations with the exposed surface region. According to a second aspect of the present invention, there is provided an offshore foundation for receiving an anode structure according to any of the above statements, the offshore foundation comprising: a body; a coated surface region on the surface of the body; and an exposed surface region on the surface of the body, the exposed surface region being without the coating; wherein the body and the exposed surface region are configured for the frame of the anode structure to be attached to the body such that the electrical contact formations are aligned to contact the exposed surface region.

[0019] Preferably, the coated surface region is coated with an anti-corrosion coating. More preferably, the anti-corrosion coating is an anti-corrosion paint.

[0020] Preferably, the body comprises a plurality of exposed surface regions, and the one or more electrical

contact formations comprise a plurality of electrical contact formations for contacting the plurality of exposed surface regions.

[0021] Preferably, the body of the offshore foundation comprises a conical section, and wherein the electrically conductive frame of the anode structure comprises a upper ring and a lower ring having a larger diameter than the upper ring, and where the upper and lower rings are sized for mating with the conical section of the body at a position for aligning the one or more electrical contact formations with the exposed surface region.

[0022] According to a third aspect of the present invention, there is provided an assembly comprising an anode structure according to any of the above statements and an offshore foundation according to any of the above statements.

[0023] According to a fourth aspect of the present invention, there is provided a method for reducing corrosion in an offshore foundation comprising: providing an offshore foundation according to any of the above statements; providing an anode structure according to any of the above statements; and attaching the anode structure to the body of the offshore foundation such that the one or more electrical contact formations contact the exposed surface region.

BRIEF DESCRIPTION OF DRAWINGS

Reference Numbers

[0024]

- 1 - Anode structure;
- 2 - Monopile body;
- 3 - Upper Ring;
- 4 - Anode Pipes;
- 5 - Anode material;
- 6 - Lower Ring;
- 7 - Coated surface region;
- 8 - Exposed surface region;
- 9 - Contact formation;
- 10 - Connection element(s);
- 11 - Auxiliary access strip.

[0025] Illustrative embodiments of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 shows a side view of a section of a monopile body with an anode cage according to an embodiment of the invention;

Figure 2 shows a horizontal cross-section view of the top of the anode cage shown in Figure 1;

Figure 3 shows a vertical cross-sectional view through one anode element of the anode cage when contacting to the monopile body;

Figure 4 shows an enlarged vertical cross-sectional view through the contacting ends of the anode cage

shown in Figure 3; and

Figure 5 shows an enlarged horizontal cross-sectional view of the contact formation of an anode element.

DETAILED DESCRIPTION OF THE INVENTION

[0026] An anode structure 1 according to an illustrative embodiment of the invention will now be described in reference to Figures 1 to 5. In this embodiment, the anode structure 1 is provided as an anode cage.

[0027] As shown in Figures 1 and 2, the anode cage 1 comprises a frame formed of an upper ring 3, a lower ring 6, and a plurality of anode pipes 4 connecting between the two rings. The frame may be made of engineering steel and is configured to receive the monopile body 2 through its bore, as shown in Figure 1, and from above in Figure 2. The lower ring 6 also has a slightly larger diameter than the upper ring 3 so that the anode cage 1 fits over and mates to the conical section of the body 2. In embodiments where the monopile is not conical, the connection points for the anode cage 1 may be welded or otherwise installed onto the monopile.

[0028] As shown in further detail in Figure 3, each anode pipe 4 comprises a jacket of anode material 5 surrounding the section of anode pipe 4 between the upper and lower rings 3 and 6. As such, each jacket of anode material 5 forms an anode element between the two rings 3 and 6. The anode material 5 is formed of a material having a lower electrode potential than the body of the monopile 2. As such, suitable anode materials are less noble metals, such as zinc or magnesium, or alloys thereof. The anode material 5 is electrically connected to the anode pipe 4 and, in turn, the upper and lower rings 3 and 6.

[0029] Figure 1 shows a side view of a section of the monopile body 2. The bulk of the body's surface is covered in an anti-corrosion paint 7. However, the body 2 further comprises an unpainted horizontal strip 8 around its circumference. The width of the strip 8 is relatively large to allow for tolerances in the position of where the anode cage sits when fitted, and in preferred embodiments may be 1-2 meters wide. With the above described arrangement, the surface of the monopile body 2 is substantially defined by a larger coated region 7 and a smaller uncoated region 8 which exposes the underlying substrate material of the body 2. That said, in this particular embodiment, the monopile body 2 is further provided with an auxiliary access strip 11 located below the unpainted horizontal strip 8 for allowing a cable to be separately retrofitted between the monopile body 2 and the anode cage 1 if the primary electrical connection described below is disrupted.

[0030] As is described in further detail below, the lower ring 6 is provided with a plurality of connection elements 10 which can be securely fastened to the monopile body 2 once the anode cage 1 has been correctly positioned.

[0031] Figure 3 shows a vertical cross-sectional view

through one of the anode elements 5 when contacting the monopile body 2.

[0032] Figure 4 shows enlarged views of each end of the anode element shown in Figure 3. As shown, the middle of the anode pipe 4 is surrounded by anode material 5, and its ends terminate in the upper and lower rings 3 and 6.

[0033] In this anode pipe 4, the end terminating with the lower ring 6 is provided with a connection element 10 which, once the anode cage is installed, rests on the monopile body 2 and stabilises the cage structure 1. In embodiments, the connection elements 10 may be fastened to the monopile body 2 to secure the anode cage in position.

[0034] Furthermore, in this anode pipe 4, the end terminating with the upper ring 3 is provided with a contact formation 9 which, once the anode cage is installed, aligns with the uncoated region 8 on the monopile body 2.

[0035] In this connection, Figure 5 shows an enlarged horizontal cross sectional view of the contact formation 9. In this embodiment, the contact formation 9 comprises two inwardly projecting projections which engage with the surface of the uncoated region 8 to provide an electrical connection thereto. In this embodiment, the two projections of the contact formation 10 project inward by different distances. That is, one of the projections is a primary projection that extends further inward than the other, secondary projection. As such, the primary projection forms the primary electrical connection with the body 2, with the secondary projection providing a backup contact in the event that the primary projection fails or is otherwise damaged.

[0036] Although the anode pipe 4 shown in Figures 3 and 4 is associated with both a connection element 10 and contact formation 9, it will be understood that not every anode pipe 4 needs to have these. That is, a smaller number of connection elements 10 and contact formations 9 may be distributed around the anode cage to provide a simplified arrangement. As such, some anode pipes 4 may simply provide the framework between the upper and lower rings 3 and 6.

[0037] In use, once the monopile has been installed, the anode cage 1 may be lowered over the monopile body 2 until the contact formations 9 align and engage with the uncoated region 8. At this stage, the connection elements 10 may also rest on the surface of the body 2 at a fixing location. The connection elements 10 may then be fastened at the fixing location for securing the anode cage 1. The anode elements 5 are thereby electrically connected to the monopile 2 and, owing to their lower electrode potential, act to provide galvanic corrosion resistance. In this way, when exposed to water, the anode material 5 will be sacrificially corroded, rather than the monopile 2.

[0038] Advantageously, the present invention allows the anode structure 1 to be electrically connected directly to the foundation body 2, without requiring separate connection cables. This thereby allows for more straightforward

ward installation and a more reliable earthing connection between the structures. The present invention also avoids or minimises the need to employ divers or ROVs devices to install the anode structure.

[0039] It will be understood that the embodiment illustrated above shows an application of the invention only for the purposes of illustration. In practice the invention may be applied to many different configurations, the detailed embodiments being straightforward for those skilled in the art to implement.

[0040] For example, the anode structure and the foundation itself may be constructed from a variety of materials. It will also be understood that the various foundation types and configurations may be used. It is also preferable that the anode structure comprises at least 3 contact elements 10 and connection formations 9 for assuring mechanical and electrical connections to the foundation body.

[0041] In another preferred embodiment, anode structure may further comprise sensors as auxiliary means for monitoring the status of the foundation.

[0042] In a preferred embodiment, the anode cage is generally made of steel or similar metal (black steel, galvanized steel, etc.), the anodes are fixed on dedicated inserts which are generally welded and/or bolted on the upper and lower ring. The supports connecting the anode cage to the foundation via direct contact are welded or bolted to the upper ring (or alternatively to the lower ring or both to upper and to lower ring).

[0043] In some embodiments, the weight of the anode cage itself causes the frame and/or the supports to deform to enhance the contact area between supports and the foundation body. The supports can be made of any conductive material, such as steel or copper.

[0044] During preferred installation methods, the anode cage is positioned by means of a suitable crane, and simply lowered onto the foundation body until it finally sits in the planned position. In embodiments, no specific orientation is required as the anode cage can be freely oriented since it is not necessary to align any cables or connection terminals to establish the electric connectivity between the anode cage and the foundation.

Claims

1. An anode structure (1) for connection to an offshore foundation having a body (2) with a coated surface region (7) and an exposed surface region (8) without a coating, the anode structure (1) comprising:

one or more anode elements (5) formed of a material having a more negative electrode potential than the body of the offshore foundation; an electrically conductive frame (3,4,6) for supporting the one or more anode elements (5) and for attachment to the body (2) of the offshore foundation;

wherein the electrically conductive frame (3,4,6) comprises one or more electrical contact formations (9) for contacting the exposed surface region (8) when the frame is attached to the body (2).

2. An anode structure (1) according to claim 1, wherein said structure (1) is an anode cage.
3. An anode structure (1) according to claims 1 or 2, wherein the offshore foundation is a monopile.
4. An anode structure (1) according to any one of claims 1-3, wherein the coated surface region (7) is coated with an anti-corrosion coating.
5. An anode structure (1) according to claims 4, wherein the anti-corrosion coating is an anti-corrosion paint.
6. An anode structure (1) according to any preceding claim, wherein the one or more electrical contact formations (9) comprise a plurality of electrical contact formations (9) for contacting the exposed surface region (8).
7. An anode structure (1) according to any preceding claim, wherein the electrical contact formations (9) project inward from the electrically conductive frame (3,4,6).
8. An anode structure (1) according to any preceding claim, wherein the body (2) of the offshore foundation comprises a conical section, and wherein the electrically conductive frame (3,4,6) comprises an upper ring (3) and a lower ring (6) having a larger diameter than the upper ring (3), and where the upper and lower rings are sized for mating with the conical section of the body (2) at a position for aligning the one or more electrical contact formations (9) with the exposed surface region (8).
9. An offshore foundation for receiving an anode structure (1) according to any preceding claim, the offshore foundation comprising:

a body (2);
a coated surface region (7) on the surface of the body; and
an exposed surface region (8) on the surface of the body, the exposed surface region (8) being without the coating;
wherein the body (2) and the exposed surface region (8) are configured for the frame (3,4,6) of the anode structure (1) to be attached to the body (2) such that the electrical contact formations (9) are aligned to contact the exposed surface region (8).

10. An offshore foundation according to claim 9, wherein the coated surface region (7) is coated with an anti-corrosion coating.
11. An offshore foundation according to claim 10, wherein the anti-corrosion coating is an anti-corrosion paint. 5
12. An offshore foundation according to any of claims 9-11, wherein the body (2) comprises a plurality of exposed surface regions (8), and the one or more electrical contact formations (9) comprise a plurality of electrical contact formations (9) for contacting the plurality of exposed surface regions (8). 10
13. An offshore foundation according to any of claims 9-12, wherein the body (2) of the offshore foundation comprises a conical section, and wherein the electrically conductive frame (3,4,6) of the anode structure (1) comprises an upper ring (3) and a lower ring (6) having a larger diameter than the upper ring (3), and where the upper and lower rings are sized for mating with the conical section of the body (2) at a position for aligning the one or more electrical contact formations (9) with the exposed surface region (8). 15 20 25
14. An assembly comprising an anode structure according to any one of claims 1-8 and an offshore foundation according to any one of claims 9-13. 30
15. A method for reducing corrosion in an offshore foundation comprising:
- providing an offshore foundation according to any one of claims 9-13; 35
- providing an anode structure (1) according to any one of claims 1-8; and
- attaching the anode structure (1) to the body (2) of the offshore foundation such that the one or more electrical contact formations (9) contact the exposed surface region (8) . 40

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FIG. 1

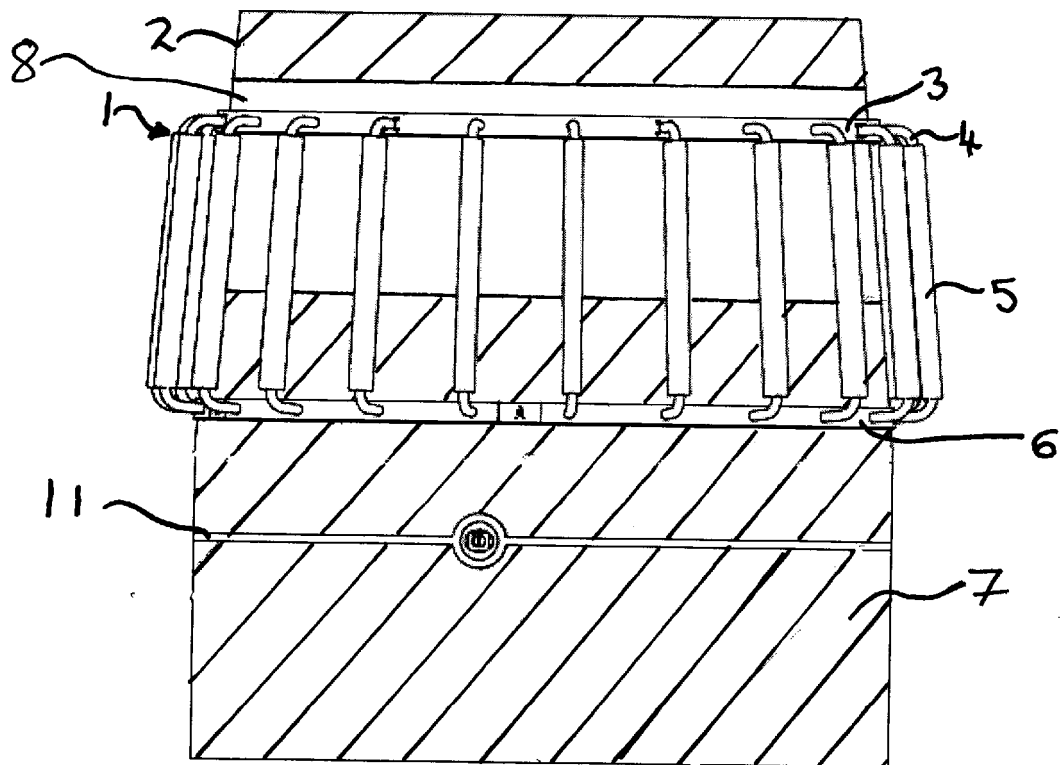


FIG. 2

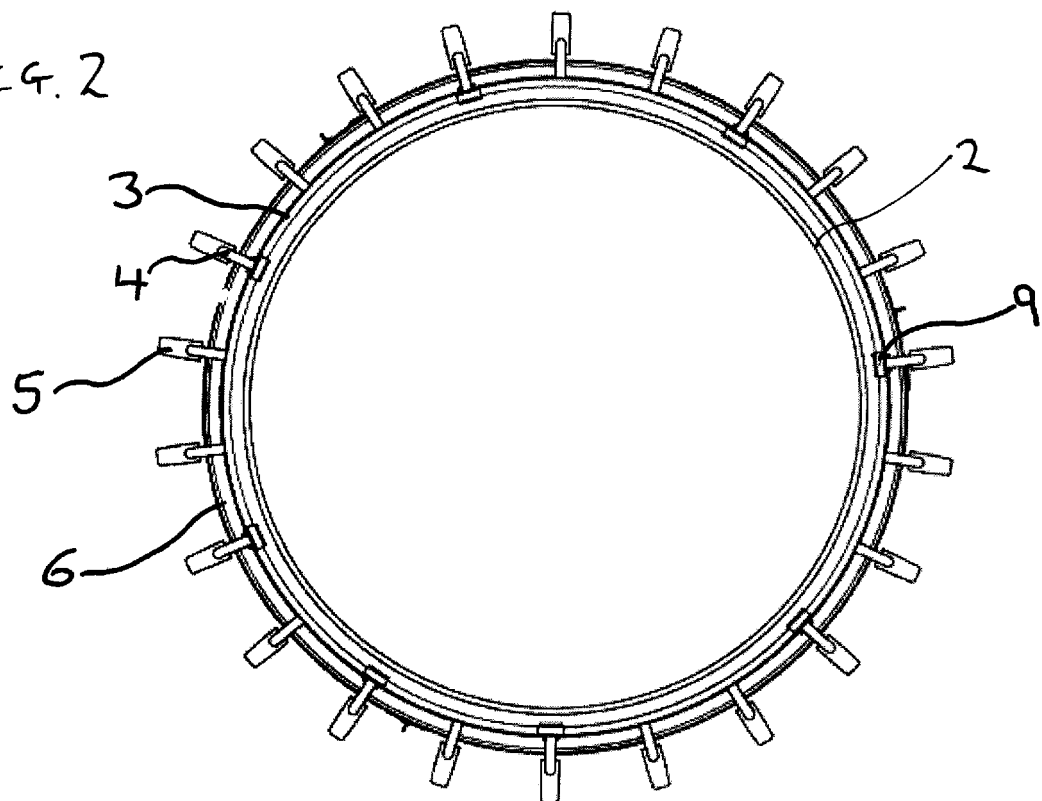


FIG. 3

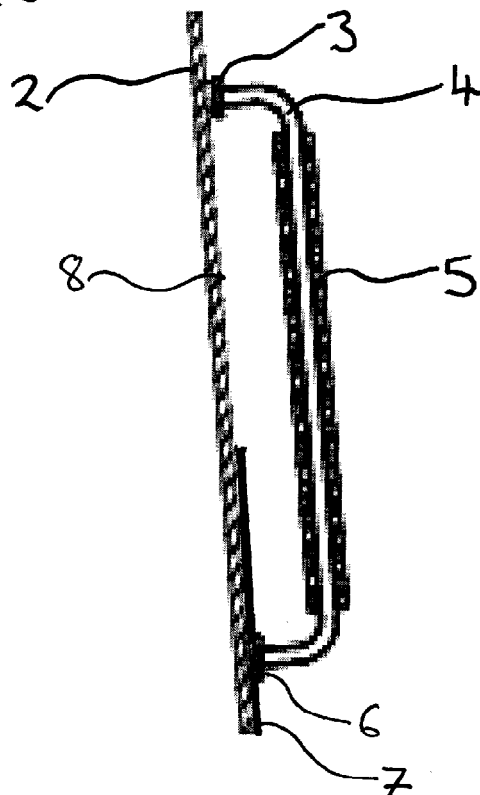


FIG. 4

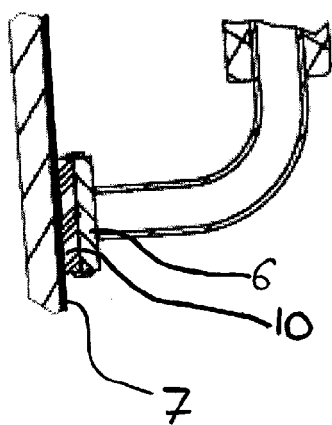
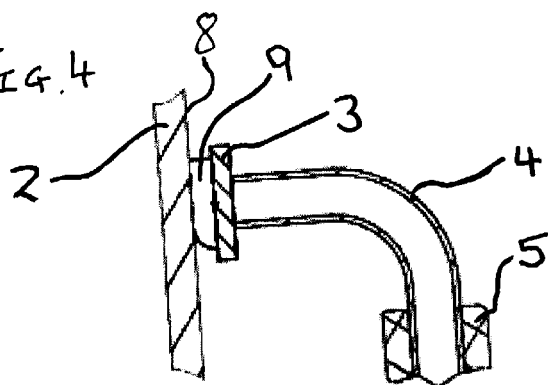
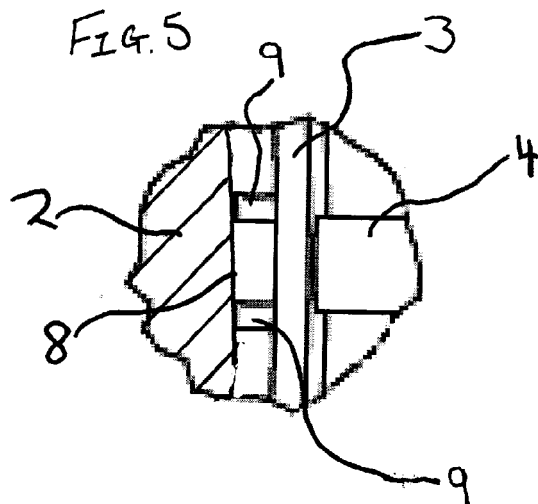


FIG. 5



REFERENCES CITED IN THE DESCRIPTION

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