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(54) DOUBLE TOP SUCTION PILE AND SUCTION PILE FOUNDATION

SAUGPFAHL MIT DOPPELTER SPITZE UND SAUGPFAHLFUNDAMENT

PIEUX À ASPIRATION À DOUBLE SOMMET ET FONDATION DE PIEUX À ASPIRATION

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(56) References cited:

WO-A1-2010/068119

WO-A2-03/099646

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Description

[0001] The invention relates to a suction pile, a foundation made from one or more suction piles and an offshore structure resting on a foundation of one or more suction piles.

[0002] Suction piles and their way of installing are a.o. known from GB-B-2300661 and EP-B-0011894, which disclosures are enclosed in here by reference. Briefly, a suction pile is a thin walled steel sleeve or pipe or cylinder, which cylinder is closed at its longitudinal top end by a bulkhead or different sealing means and which cylinder is sealingly located on the subsea bottom with the open end opposite the bulkhead since this open end penetrates the subsea bottom due to the weight of the suction pile. Thus the cavity, also called suction space, delimited by the cylinder and the bulkhead is sealed by the subsea floor such that vacuum or suction can be generated by removing water from within the suction space such that a resulting force tends to force the suction pile deeper into the subsea floor. The creation of the suction can be with the aid of a suction source, such as a pump, being on, or close to or at a distance from the suction pile and connected to the suction space. The applied level of the suction can be e.g. at least substantially constant, smoothly increase or decrease or else pulsate, for which there are convenient means. After use, the suction pile can easily be removed by creating an overpressure within the suction space, e.g. by pumping in (sea) water.

[0003] A self installing platform applying suction piles is known from e.g. WO99/51821 (SIP1) or EP-A-1 101 872 (SIP2) of the present inventor. WO 02/088.475 (Suction Pile Technology, SIP3) discloses a tower carrying a wind turbine at the top and suction piles as foundation.

[0004] US8025463 discloses an offshore foundation system having an assembly of spaced suction piles and a reaction base connecting the suction piles. The closed suction pile top projects a distance above the bottom face of the reaction base such that, in use, a gap remains between the top of a soil plug inside the suction space and the closed suction pile top.

[0005] WO 03/099646 discloses a seabed anchor provided by a suction pile having within its suction space a seabed soil retaining means embodied by a top down oriented cone with sharp angled apex. This anchor is designed for a seabed of fluent mud.

[0006] One of the benefits of suction piles is that a marine structure can be designed to be self founding or self installing by providing it with one or more suction piles. So the hoisting device and the plant for installing the foundation, e.g. hammering device, can be eliminated.

[0007] Since the structure is provided with one or more suction piles, removal after use is made easier in that by pressing out the suction pile, the anchoring of the structure to the underwater bottom can be removed.

[0008] Preferably each suction pile has one or more of: a diameter of at least 5 metres; a height of at least 5

metres; a wall thickness of at least 1 centimetre; the longitudinal axis of the suction pile and the relevant supporting leg (of the upper structure to be supported by the suction pile) are substantially in line.

OBJECT OF THE INVENTION

[0009] The object of the invention is versatile. In an aspect the reliability and/or quality of the foundation is improved. In an aspect the installation of the foundation is facilitated. In an aspect removal of the foundation is facilitated.

[0010] The object is obtained by providing within the suction pile near the top bulkhead and spaced from this bulkhead a pre-installed, fixed load bearing surface designed to keep the suction pile immovable while the offshore structure resting onto it is in full operation and which load bearing surface is fluid permeable to provide a fluid connection between the suction pile inner spaces above and below it. Thus the load bearing surface replaces the top bulkhead for the load bearing capacity it offers while used as a foundation body. Obviously, the suction pile provided with the load bearing surface is a prefabricated object, thus containing the load bearing surface prior to penetration of the suction pile into the seabed.

[0011] Preferably, the load bearing surface is located within the suction space such that the suction space is present below and above the load bearing surface or, in other words, the suction spaces above and below the load bearing surface are in mutual fluid communication through the load bearing surface.

[0012] Such load bearing surface can be a flat metal sheet but also a conical shaped metal sheet or a grid or lattice of mutually crossing beams or a sheet of geotextile or geogrid (commonly named geosynthetics). A grid/lattice/geosynthetic is fluid permeable by nature. A metal sheet could be perforated or its outer circumference keeps a gap with the axial boundary of the suction pile. The load bearing surface could also be provided by the lower face of a fluid permeable slab which completely fills the space between the top bulkhead and the bearing surface. Such slab could be prefabricated and subsequently mounted into the suction pile, or could be obtained by fabrication in situ by casting a material against the top bulkhead and allowing it to solidify. Such slab could also be provided by a layer of non coherent granules, e.g. stones, retained by a sheet providing the load bearing surface, e.g. a permeable structure of interwoven wires or a perforated metal sheet, such that the granules are retained between the load bearing surface and the top bulkhead. Such slab could completely fill the space captured between the top bulkhead and the load bearing surface or could leave a gap with the top bulkhead.

[0013] The bearing load from the load bearing surface could be transferred to the suction pile side wall in which case the load bearing surface preferably is inflexible or rigid, e.g. provided with or made from stiffeners, e.g. I-

beams. Alternatively such load is transferred to the top bulkhead in which case incompressible elements (e.g. the slab completely filling the space between the load bearing surface and the top bulkhead, or girders bridging the distance between the load bearing surface and the top bulkhead) between the load bearing surface and the top bulkhead are applied which are compression loaded.

[0014] The invention is based on the recognition that transferring the required load bearing capacity from the top bulkhead to a lower level increases the stability of the foundation dramatically. With prior art suction piles the top bulkhead provides the required load bearing capacity for the suction pile to function as a foundation body and it occurred that after completion of sucking the suction pile completely into the sea floor, the suction pile was pushed deeper into the sea floor by the upper structure placed on top of the suction pile which according to the design calculations of the foundation such was impossible to occur. This made the behaviour of the foundation unpredictable. It came out that by providing the load bearing capacity at a lower level at the suction pile, such unpredictable behaviour of the foundation was eliminated. Based on speculation a reason could be that if the load bearing surface is no longer provided by the top bulkhead and provided at a level below the top bulkhead, the load distribution across such load bearing surface becomes more equal, resulting in more and immediate stability. Without to be bound by theory it is believed that remote from the top bulkhead, at the level of the inventive load bearing surface, the upright wall of the suction pile functions as a skirt which ensures complete contact between the load bearing surface and the soil plug within the suction pile.

[0015] On the other hand extraction from the seabed of the suction pile according to the invention is easier compared to the prior art suction pile, in case an overpressure within the suction space is applied to force the suction pile from the seabed opposite the way in which the suction pile penetrated the seabed by creation of suction within the suction space. Without to be bound by theory it is believed that the invention ensures equal distribution of the overpressure within the suction space, which makes extraction more reliable.

[0016] It is noted that the invention is directed to suction piles for foundations, in other words designed to carry the weight of an upper structure placed on top, to avoid that such upper structure sinks into the subsea bottom. Thus a foundation suction pile bears loads from the associated upper structure which tend to force the suction pile further into the ground. The fixed bearing surface spaced below the top bulkhead is designed to prevent that the suction pile moves deeper into the subsea bottom due to the pushing loads generated by the weight of the upper structure. A foundation suction pile is by the nature of its loading different from a suction pile for anchoring, which anchoring suction pile must withstand pulling forces from the anchored object which tries to leave its desired location by trying to pull the anchoring suction pile

out of the subsea bottom.

[0017] Preferably one or more of the following applies: the load bearing surface is parallel to the top bulkhead; the suction required to penetrate the suction pile into the subsea bottom during installation is generated within the suction pile above the load bearing surface, preferably since the suction side of a suction pump means is connected to the suction space above the load bearing surface, e.g. the top bulkhead is provided with a nozzle or different sealable port for fluid connection of the suction space with a suction pump means; the diameter of the suction pile is constant over its height (the height is the direction from the top bulkhead towards the opposite open end); from the top bulkhead the cylinder walls of the suction pile extend parallel; the open end of the suction pile, designed to be located on the sea floor first is completely open, in other words, its aperture is merely bordered by the cylinder walls; the water depth is such that the suction pile is completely below the water surface when its lower end contacts the sea floor, in other words when its lower end has not penetrated the sea floor yet; the foundation comprises one, two, three, four or more mutually spaced suction piles; the load bearing surface has a permeability of at least 10% or 20%, in other words at least 10% or 20% of the cross sectional surface area of the suction space at the level of the load bearing surface allows free passage of fluid between above and below the load bearing surface; the load bearing surface is at least 10 or 20 or 50 centimetre and/or 1 or 1.5 or 2 metre to a maximum below the top bulkhead; the cone shaped load bearing surface is shallow and the cone angle is obtuse, preferably is limited to between 180 (flat sheet) and 120 degrees; with the penetration of the suction pile into the sea floor completed, the top bulkhead is spaced from the sea floor and/or the load bearing surface bears onto the sea floor which is possibly at elevated level within the suction pile, compared to the seafloor level external from the suction pile, due to raising of the seabed plug within the suction space caused by penetration of the suction pile into the seabed;

[0018] The suction pile is also preferably provided with known as such valves and/or hatches adjacent or at its top bulkhead for selectively allowing water and air to enter or exit the suction space through the top side of the suction pile.

[0019] An offshore foundation system or a suction pile of said system, the suction pile preferably provided by an open bottom and closed top, advantageously cylindrical, elongate shell providing a suction compartment or suction space, said closed top having an externally facing upper face and an opposite, toward the suction space facing lower face and preferably provided with one or more valves selectively allowing fluid communication between the suction space and the environment, the suction space being provided with a preferably fixedly located load bearing surface oriented perpendicular to the longitudinal axis of the shell and there is a gap between said load bearing surface and the lower face of the closed top,

which gap preferably is in fluid communication with the suction space and wherein, in use, the load bearing surface bears onto a top of a soil plug inside the suction space, the load bearing surface preferably being provided by the bottom surface of a sheet or slab like element which is preferably integrally formed with the suction pile.

[0020] The invention is further illustrated by way of non-limiting, presently preferred embodiments providing the best way of carrying out the invention and shown in the drawings.

Fig. 1 shows a side view;

Fig. 2-13 show a top views, sectional side views and partly cutaway perspective views of four different embodiments of the suction pile;

Fig. 14 and 15 show marine structures in perspective view.

[0021] Fig. 1 shows three stages during penetration of the suction pile into the sea floor by suction within the suction space. The left hand stage is the initial stage in which the open bottom of the suction pile has penetrated the seabed by gravity, such that the suction space is sealed. The central stage is obtained by removing water from the suction space by pumping, such that suction is created within the suction space such that the suction pile penetrates deeper into the seabed, thus its top comes closer to the seabed. The right hand stage is the final stage in which the suction pile is penetrated to its final depth, providing its design load bearing capacity for a weight resting on top of it. The load bearing surface 4 spaced below the top bulkhead is shown. The top bulkhead 6 always is spaced from the sea floor 11. Within the suction space internal from the side wall 7, the surface 12 of the sea floor material rises due to penetration of the suction pile. Such seabed part captive within the suction space is also called soil plug.

[0022] Fig. 2-13 show suction piles having a load bearing surface 4 within the suction space 7 and spaced below the top bulkhead 6. A pipe stud 5 penetrates the top bulkhead to connect the suction space with a suction source. The suction space is bounded by the top bulkhead 6, the cylindrical side wall 7 and the open end 8. In all embodiments the distance between the top bulkhead and the load bearing surface measures 50 centimetre.

[0023] In fig. 2-4 the load bearing surface 4 is the bottom side of a flat sheet keeping at its circumference an annular air and water gap with the wall 7. Compression loaded girders 10 bridging the load bearing surface 4 and the top bulkhead 6 transfer the bearing load from the load bearing surface to the top bulkhead 6 through. As shown, the girders leave openings 13 to allow fluid to pass the girders in the direction perpendicular to the longitudinal axis 14 of the suction pile. In fig. 5-7 the load bearing surface 4 has a cone shape and also keeps an air and water gap with the wall 7 at its outer circumference. The opposite walls of the cone include an obtuse angle of 160 degrees, in other words the wall of the cone, vertically

oriented resting on its apex, include an angle (referred to as α in the drawing) of 10 degrees with the horizontal. In fig. 8-10 the flat load bearing surface 4 tightly fits within the cylinder 7 thus the circumferential air and water gap is absent. In stead, the sheet 4 is perforated to be air and water permeable. In fig. 11-13 the load bearing surface is the lower face 4 of a slab 9. The slab 9 is air and water permeable and the face 4 is also air and water permeable. As an alternative the slab 9 could be replaced by a layer of incoherent gravel of same thickness, captive between the top bulkhead 6 and the face 4 provided by e.g. a perforated sheet or lattice.

[0024] Fig. 14 and 15 are examples of the upper structures to be supported by the suction piles 1. The top of the upper structures is provided by a platform 2 above water level 3.

[0025] The invention is not limited to the above described and in the drawings illustrated embodiments. E.g. the marine structure can have a different number of suction piles. The number of supporting legs by which the platform rests onto the suction piles is preferably equal to the number of suction piles, but this is not absolutely necessary. E.g. three suction piles are at the corners of a structure that is triangular in top view. It is not required that the suction piles and supporting legs are at the corners of the structure. The platform can be constructed and/or shaped differently.

Claims

1. Suction pile (1) for installation in the seafloor to operate as a foundation or part of it to support an offshore structure resting onto the seafloor, the suction pile (1) having internally near a top bulkhead (6) and spaced from this bulkhead (6) a pre-installed, fixed load bearing surface (4) designed to keep the suction pile (1) from moving deeper into the seafloor while the offshore structure resting onto it is in full operation and which load bearing surface (4) is fluid permeable to provide a fluid connection between the suction pile (1) inner spaces above and below it.
2. Suction pile according to claim 1 wherein the bearing surface (4) is cone shaped and shallow and the cone angle is obtuse, preferably is limited to between 180 and 120 degrees and/or the load bearing surface is parallel to the top bulkhead.
3. Suction pile according to claim 1 or 2 and which load bearing surface comprises a metal sheet.
4. Suction pile according to claim 1, 2 or 3, the load bearing surface is at least 10 or 20 or 50 centimetre and/or 1 or 1.5 or 2 metre to a maximum below the top bulkhead.
5. Suction pile according to any of claims 1-4, being a

prefabricated object comprising the load bearing surface.

6. Offshore structure having a foundation of one or more suction piles supporting the offshore structure resting onto the seafloor, wherein at least one of the suction piles is according to any of claims 1-5 and its load bearing surface rests onto the seafloor.
7. Method of installing a suction pile according to any of claims 1-5, wherein the suction pile bottom (8) penetrates the seafloor (12) and fluid is removed from the suction space such that penetration proceeds by suction and thus the load bearing surface moves towards the seafloor and finally bears onto the seafloor, preventing continuation of further penetration and which load bearing surface is fluid permeable to provide a fluid connection between the suction pile inner spaces above and below it.
8. Method according to claim 7, wherein the suction pile before penetrating the seafloor comprises the load bearing surface and/or at the end of the method the top bulk head is at a level above the sea floor, preferably at least 10 or 20 or 50 centimetre and/or 1 or 1.5 or 2 metre to a maximum.
9. Method according to claim 7 or 8, the cone shaped load bearing surface is shallow and the cone angle is obtuse, preferably is limited to between 180 (flat sheet) and 120 degrees and/or the load bearing surface is parallel to the top bulkhead.

Patentansprüche

1. Saugpfahl (1) zum Einbau in dem Meeresboden als eine Grundlage oder einen Teil davon um eine Offshore-Struktur zu unterstützen welche auf den Meeresboden ruht, die Saugpfahl (1) ist intern in der Nähe eines oberen Schottes (6) und von diesem Schott (6) beabstandet mit einer vorinstallierten festen Tragfläche (4) versehen, die verhindern soll, dass sich der Saugpfahl (1) tiefer in den Meeresboden hineinbewegt, während sich die darauf ruhende Offshore-Struktur in vollem Betrieb befindet und welche Tragfläche (4)) fluiddurchlässig ist, um eine Fluidverbindung zwischen dem Saugpfahl (1) Innenräumen darüber und darunter herzustellen.
2. Saugpfahl nach Anspruch 1, bei dem die Tragfläche (4) kegelförmig und flach ist und der Kegelwinkel stumpf ist, vorzugsweise auf zwischen 180 und 120 Grad begrenzt ist und/oder die Tragfläche parallel zum oberen Schott verläuft.
3. Saugpfahl nach Anspruch 1 oder 2 wobei dessen Tragfläche ein Metallblech aufweist.

4. Saugpfahl nach Anspruch 1, 2 oder 3, die Tragfläche befindet sich zumindest 10 oder 20 oder 50 Zentimeter und / oder nicht mehr als 1 oder 1,5 oder 2 Meter unterhalb der oberen Schott.
5. Saugpfahl nach einem der Ansprüche 1-4, welche ein vorgefertigtes Objekt mit der Tragfläche ist.
6. Offshore-Struktur mit einer Grundlage für eine oder mehrere Saugpfähle welche die Offshore-Struktur tragen welche auf dem Meeresboden ruht, wobei zumindest eine der Saugpfähle nach einem der Ansprüche 1 -5 ist und seine Tragfläche auf dem Meeresboden ruht.
7. Verfahren zum Installieren eines Saugpfahl nach einem der Ansprüche 1-5, wobei die Saugpfahlboden (8) in den Meeresboden (12) eindringt und Flüssigkeit aus dem Saugraum entfernt wird, so dass Eindringen durch Saugwirkung erfolgt und damit der Tragfläche sich zum Meeresboden bewegt und schließlich auf den Meeresboden ruht, wodurch ein weiteres Eindringen verhindert wird und welche Tragfläche fluiddurchlässig ist, um eine fluidverbindung zwischen den Innenräumen des Saugpfahles darüber und darunter herzustellen.
8. Verfahren nach Anspruch 7, wobei der Saugpfahl vor dem Eindringen des Meeresbodens die Tragfläche aufweist und/oder sich am Ende des Verfahrens das obere Schott auf einer Höhe oberhalb des Meeresbodens befindet, vorzugsweise mindestens 10 oder 20 oder Maximal 50 Zentimeter und/oder 1 oder 1,5 oder 2 Meter.
9. Verfahren nach Anspruch 7 oder 8, wobei die kegelförmige Tragfläche flach und der Kegelwinkel stumpf ist, vorzugsweise zwischen 180 (flaches Blech) und 120 Grad begrenzt ist und/oder die Tragfläche parallel zum oberen Schott liegt.

Revendications

1. Pile d'aspiration (1) pour une installation dans le fond marin de fonctionner comme une base ou une partie de celui-ci pour supporter une structure marine reposant sur le fond marin, la pile de d'aspiration (1) présentant intérieurement près à cloison supérieure (6) et espacée de cette cloison (6) une surface porteuse fixe préinstallée (4) conçue pour empêcher le pile d'aspiration (1) de pénétrer plus profondément dans le fond marin pendant que la structure marine reposant dessus est en pleine opération et quelle surface porteuse (4) est perméable aux fluides pour fournir une connexion fluide entre la pile d'aspiration(1) espaces intérieurs au-dessus et en dessous.

2. Pile d'aspiration selon la revendication 1, dans lequel la surface porteuse (4) est en forme de cône et peu profonde et l'angle du cône est obtus, est de préférence limité entre 180 et 120 degrés et/ou la surface porteuse est parallèle à la cloison supérieure. 5
3. Pile d'aspiration selon la revendication 1 ou 2 et dont la surface porteuse comprend une tôle.
4. Pile d'aspiration selon la revendication 1, 2 ou 3, la surface porteuse est d'au moins 10 ou 20 ou 50 centimètres et/ou 1 ou 1,5 ou 2 mètres au maximum en dessous de la cloison supérieure. 10
5. Pile d'aspiration selon l'une quelconque des revendications 1 à 4, étant un objet préfabriqué comprenant la surface porteuse. 15
6. Structure marine ayant une base d'une ou plusieurs piles d'aspiration supportant la structure marine reposant sur le fond marin, dans lequel au moins l'une des piles d'aspiration est selon l'une quelconque des revendications 1-5 et sa surface porteuse repose sur le fond marin. 20
7. Procédé d'installation d'une pile d'aspiration selon l'une quelconque des revendications 1-5, dans lequel le fond (8) de la pile d'aspiration pénètre le fond marin (12) et le liquide est retiré de la chambre d'aspiration de telle sorte que la pénétration se fait par aspiration et donc la surface porteuse se déplace vers le fond marin et porte finalement sur le fond marin, empêchant la poursuite de la pénétration et quelle surface porteuse est perméable aux fluides pour fournir une connexion fluide entre les espaces intérieurs des pile d'aspiration au-dessus et en dessous. 25
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8. Procédé selon la revendication 7, dans lequel le pile d'aspiration avant de pénétrer dans le fond marin comprend la surface porteuse et/ou à la fin du procédé, la cloison supérieure est à un niveau au-dessus du fond marin, de préférence au moins 10 ou 20 ou 50 centimètres et/ou 1 ou 1,5 ou 2 mètres au maximum. 40
45
9. Procédé selon la revendication 7 ou 8, la surface porteuse en forme de cône est peu profonde et l'angle du cône est obtus, est de préférence limité entre 180 (drap plat) et 120 degrés et/ou la surface porteuse est parallèle au cloison supérieure. 50

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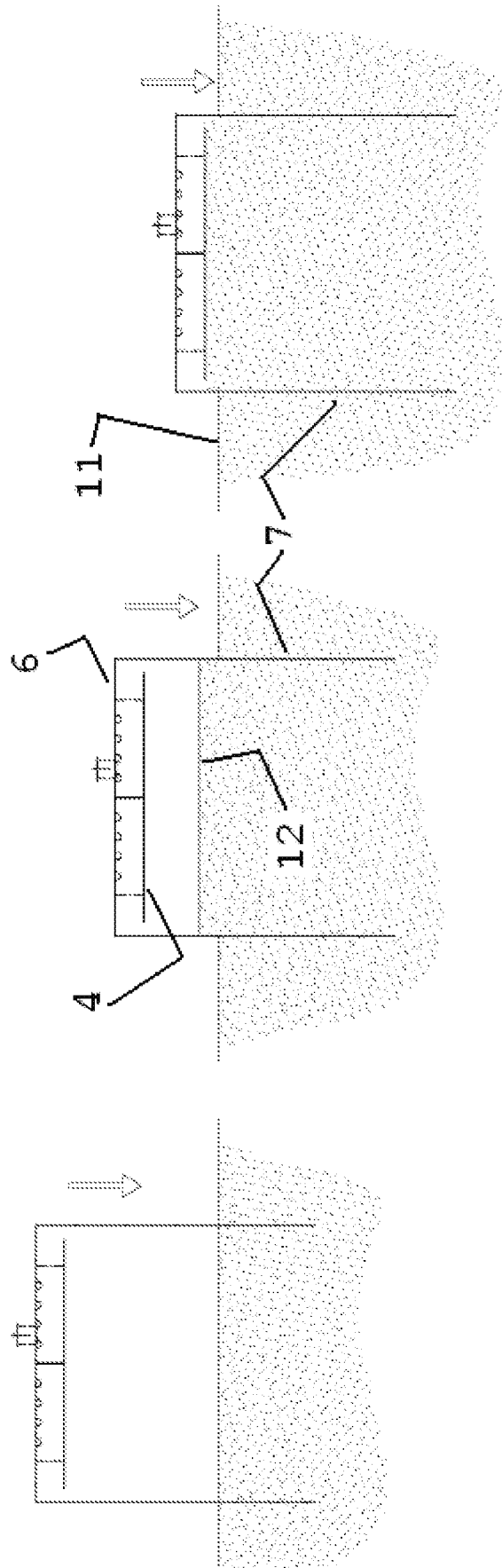
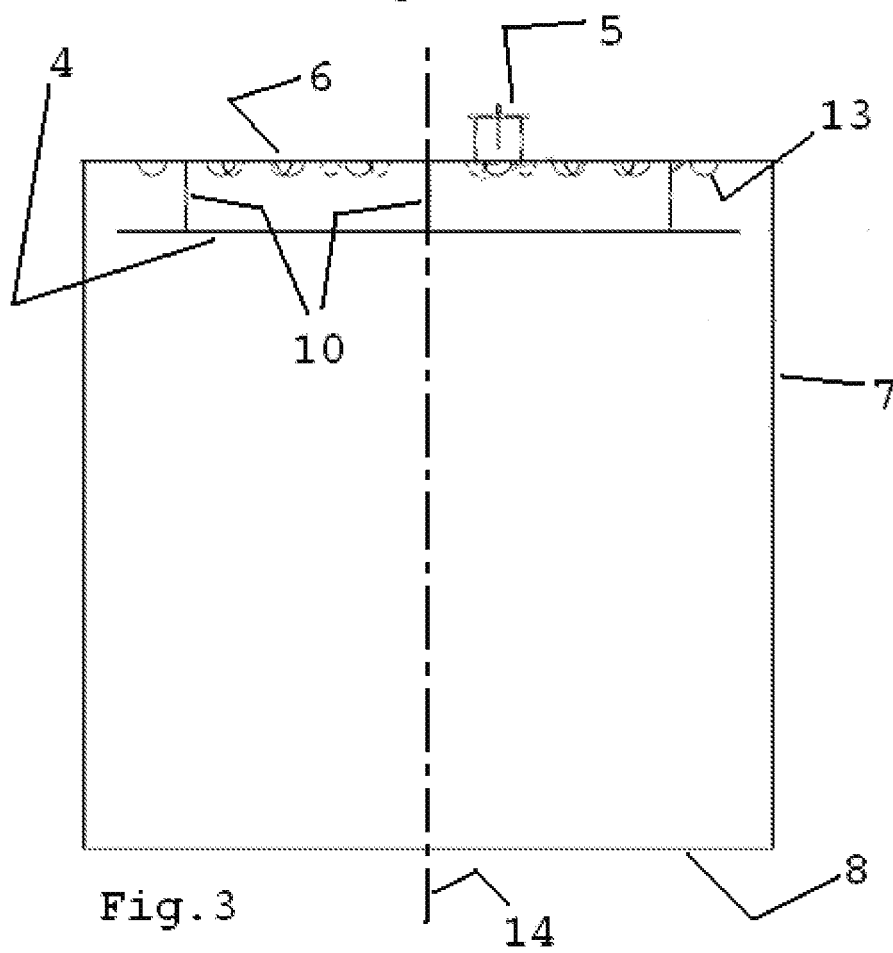
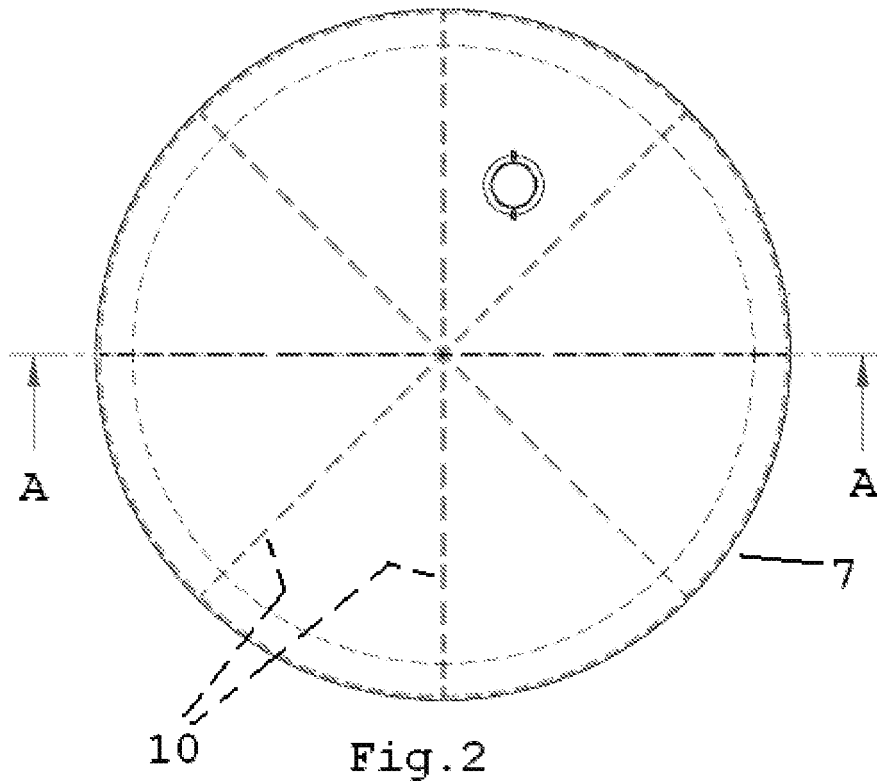


Fig.1



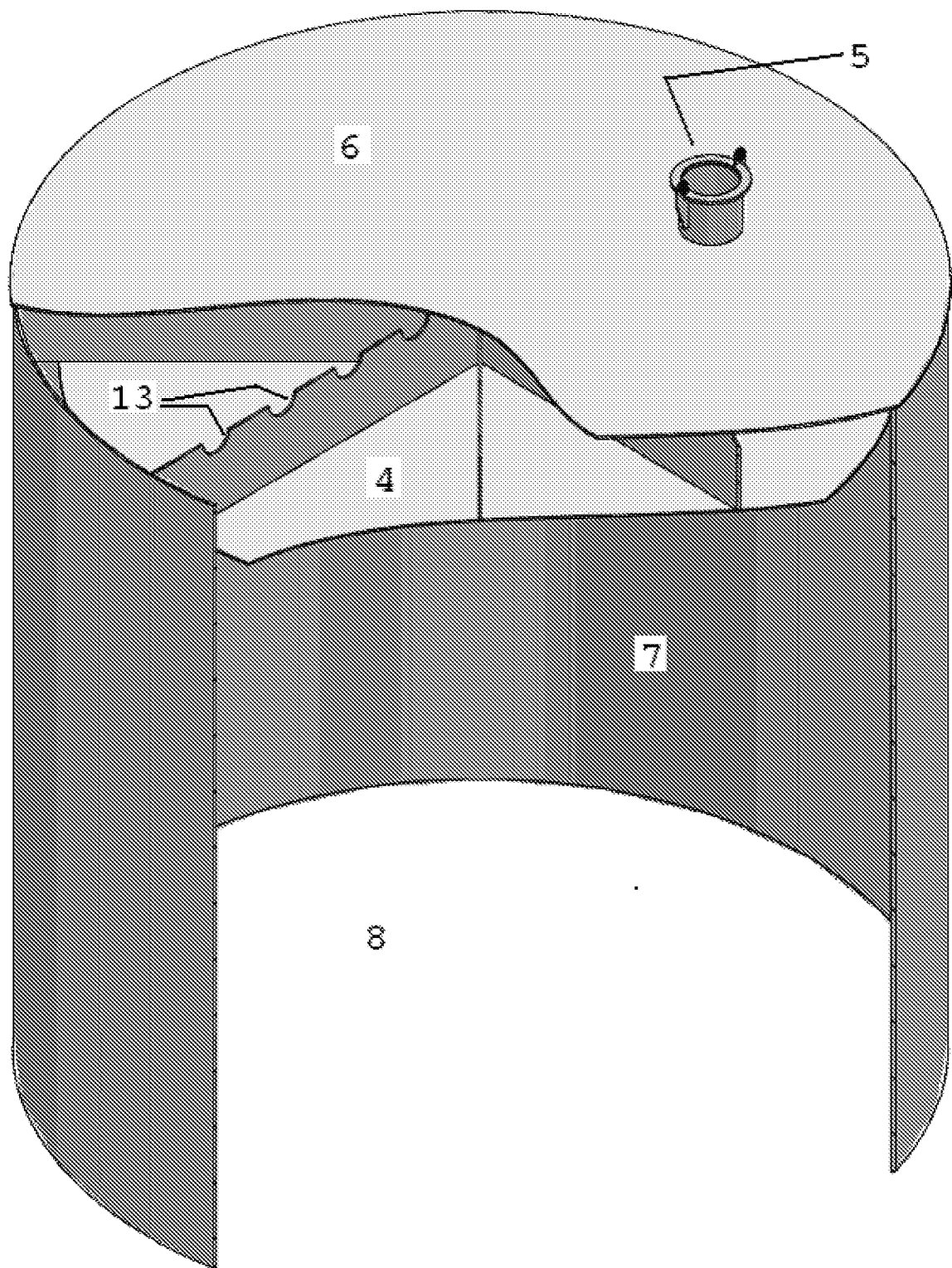


Fig. 4

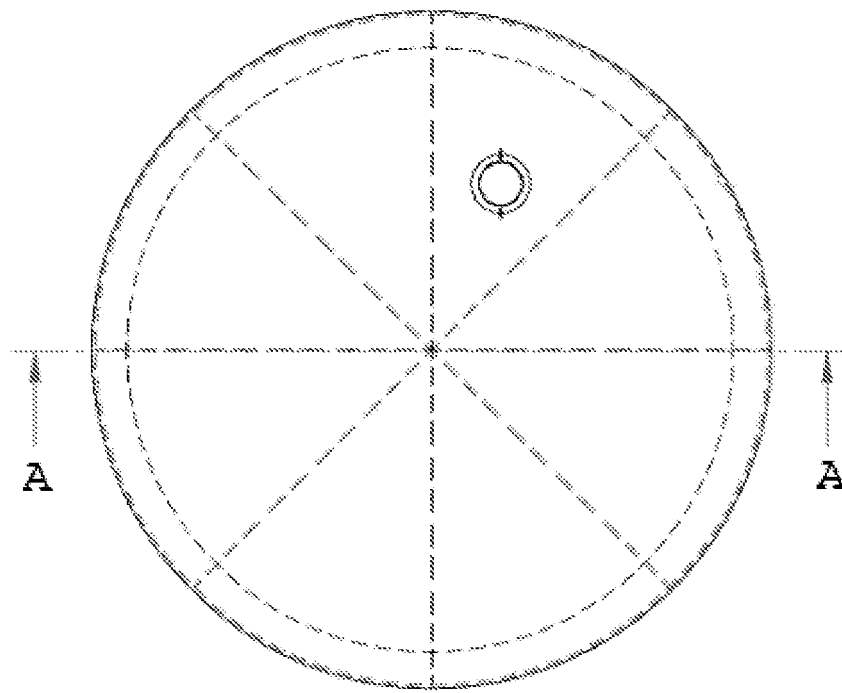


Fig. 5

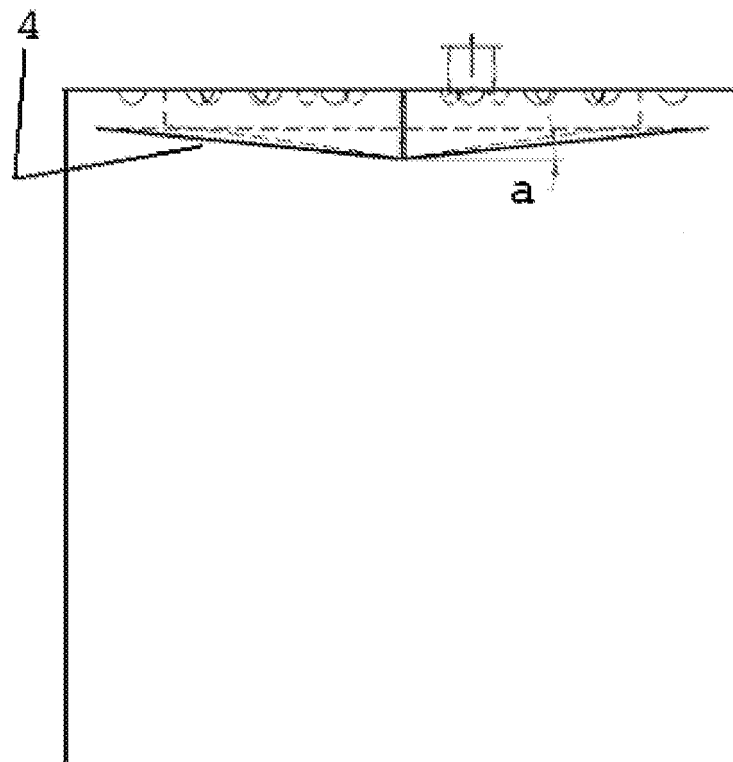


Fig. 6

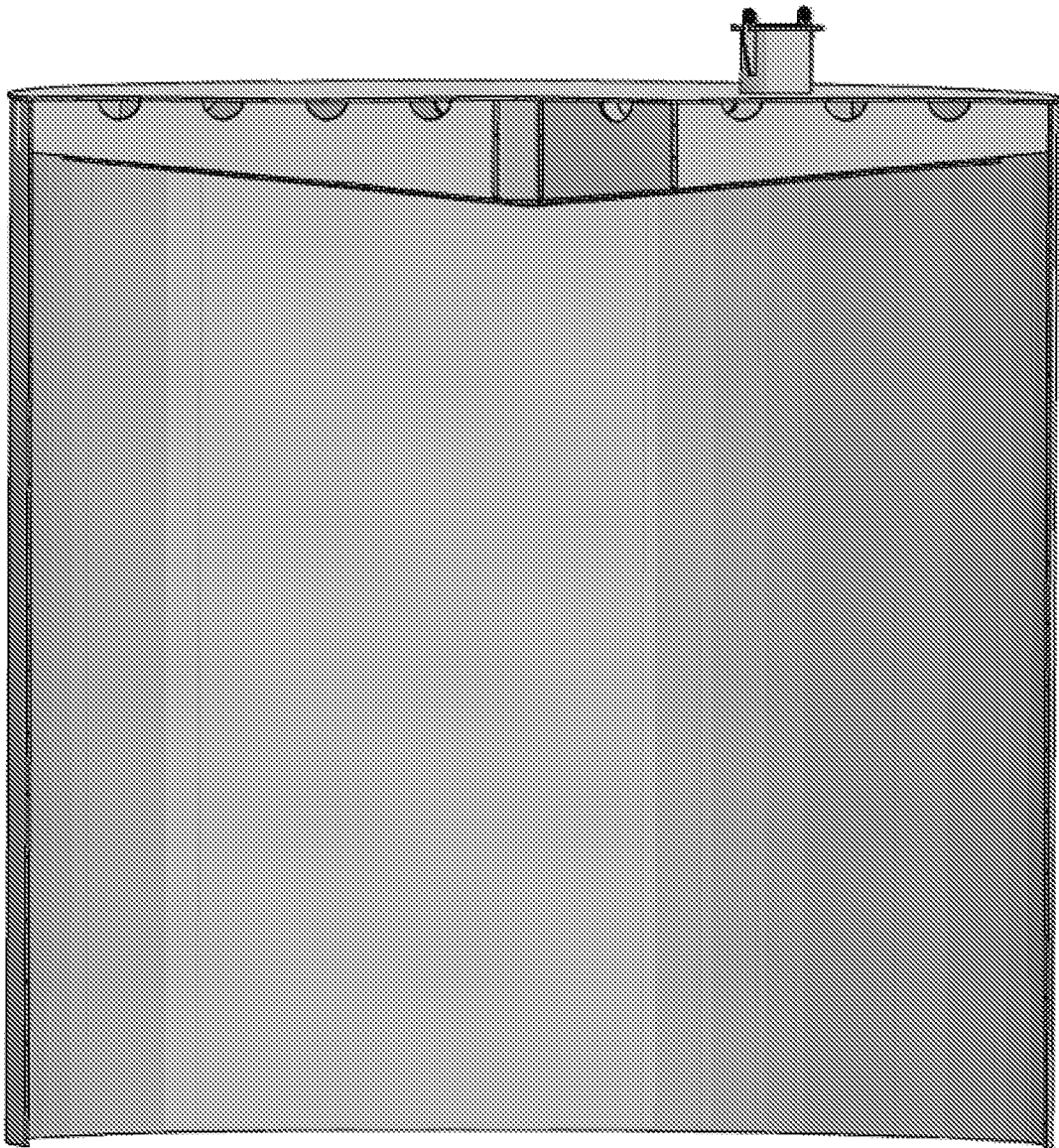


Fig. 7

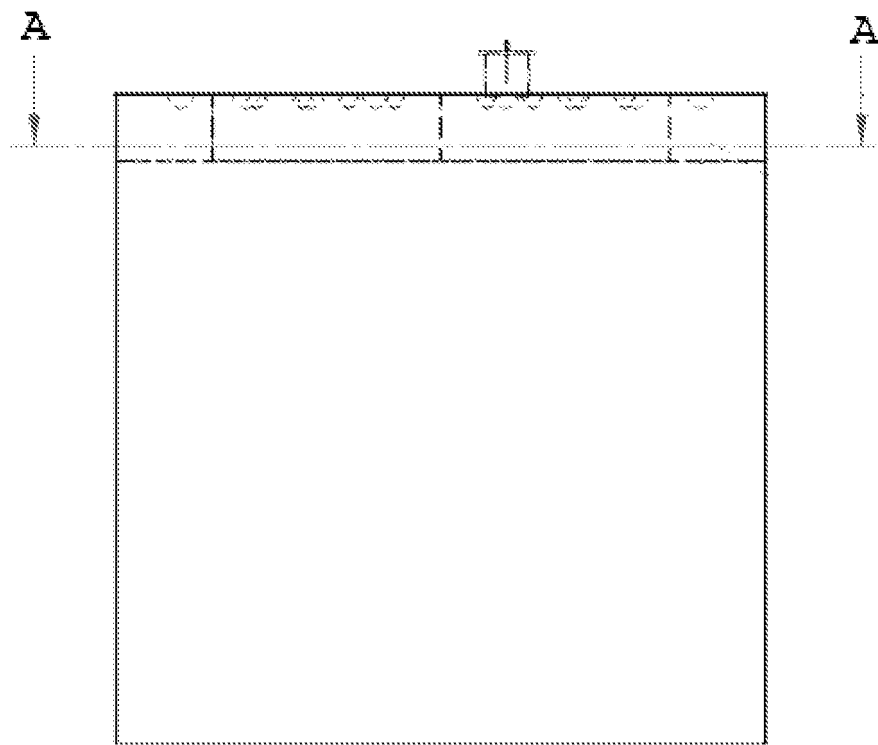


Fig. 8

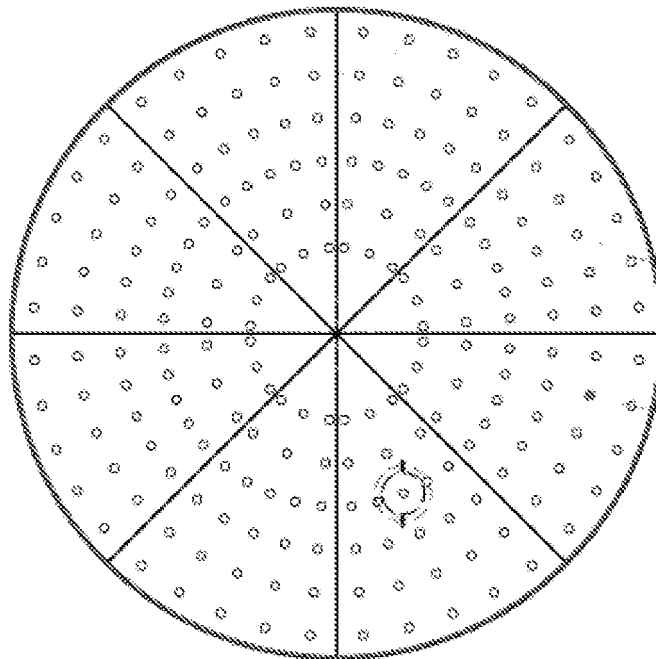


Fig. 9

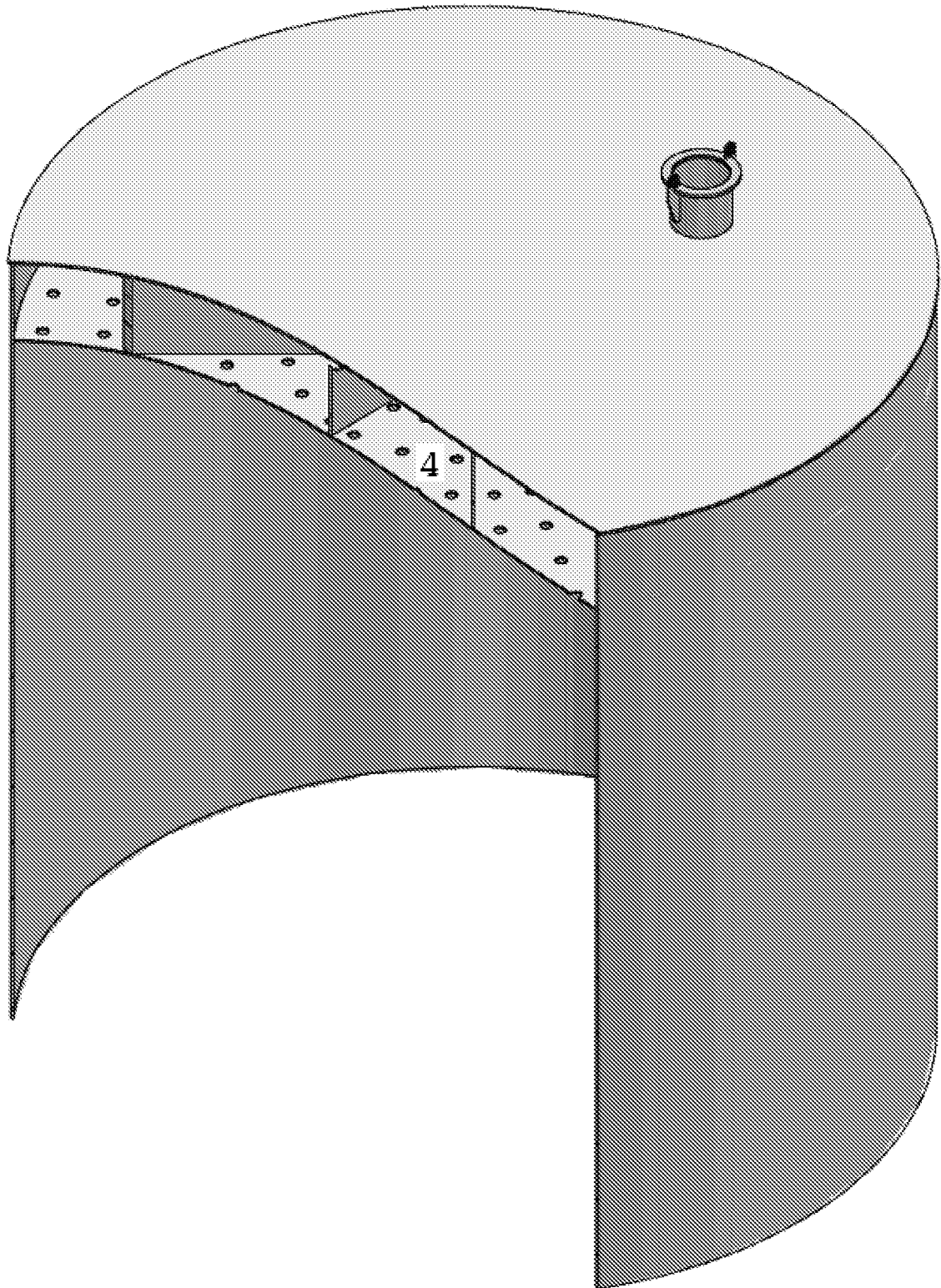


Fig. 10

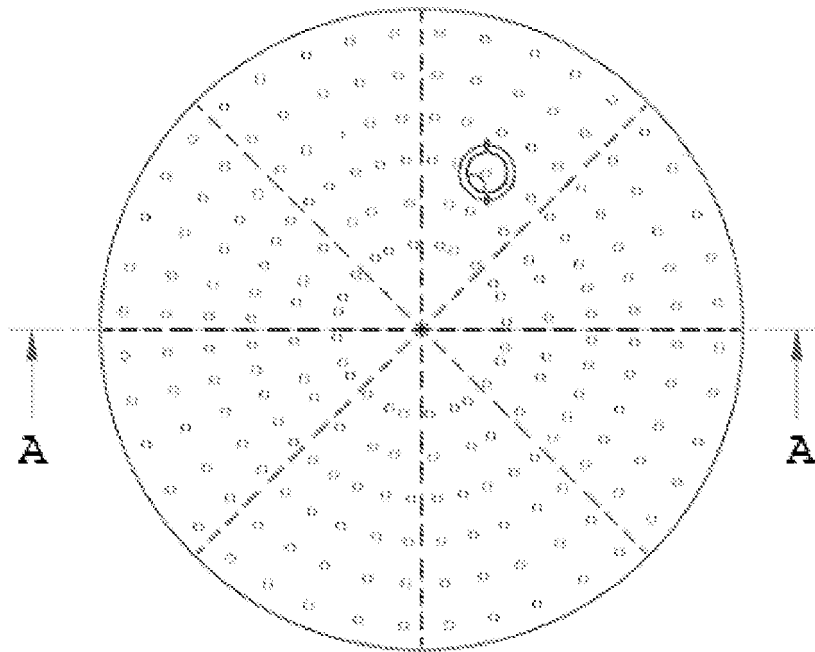


Fig. 11

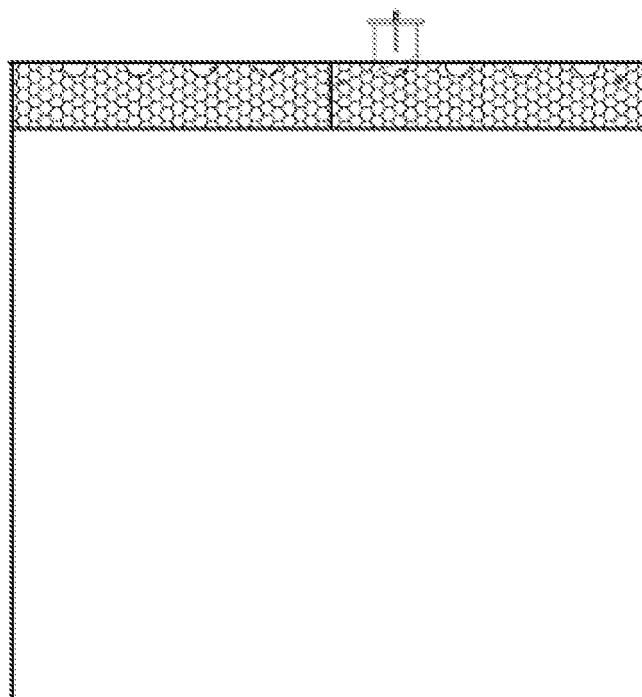


Fig. 12

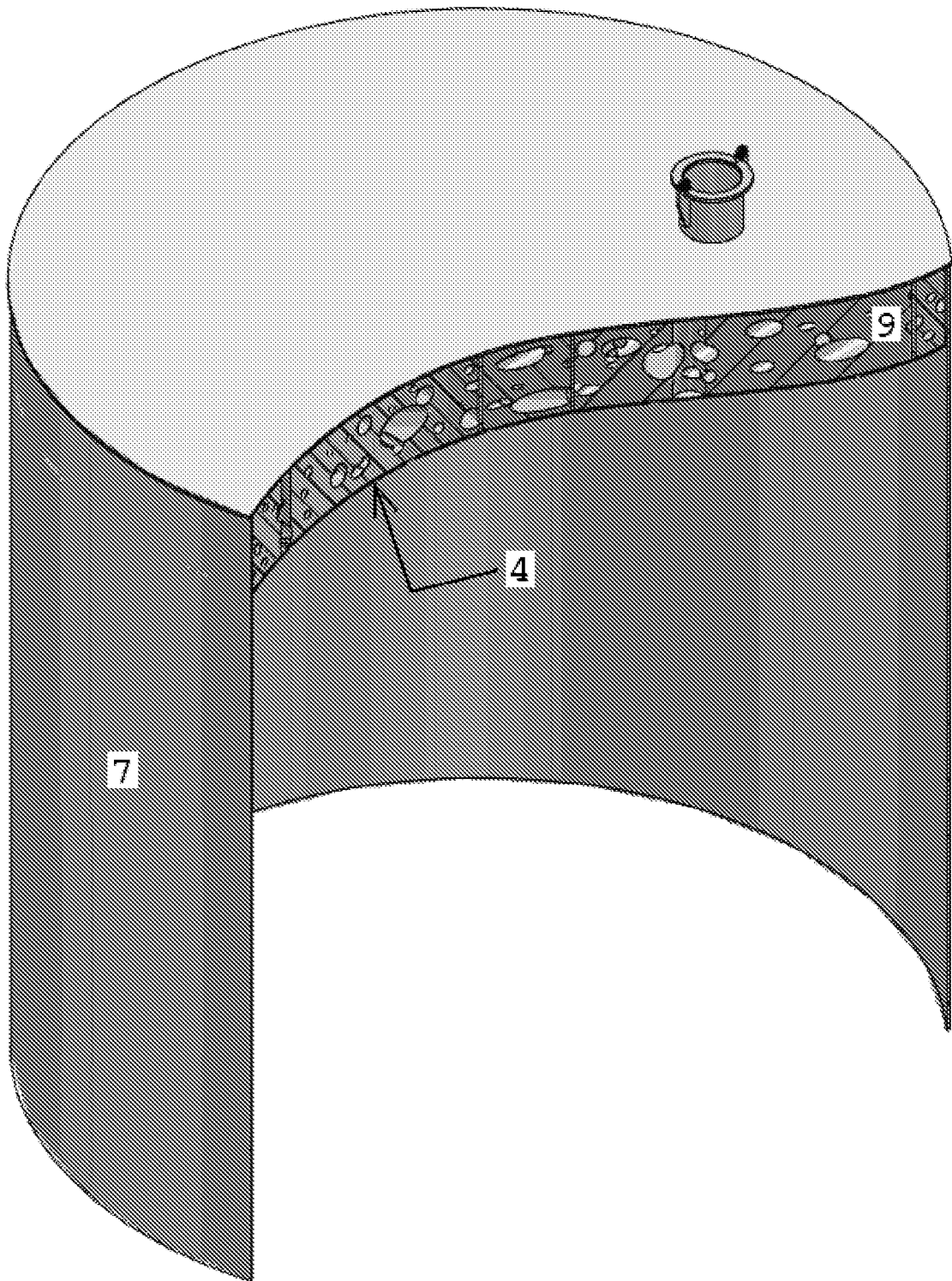


Fig. 13

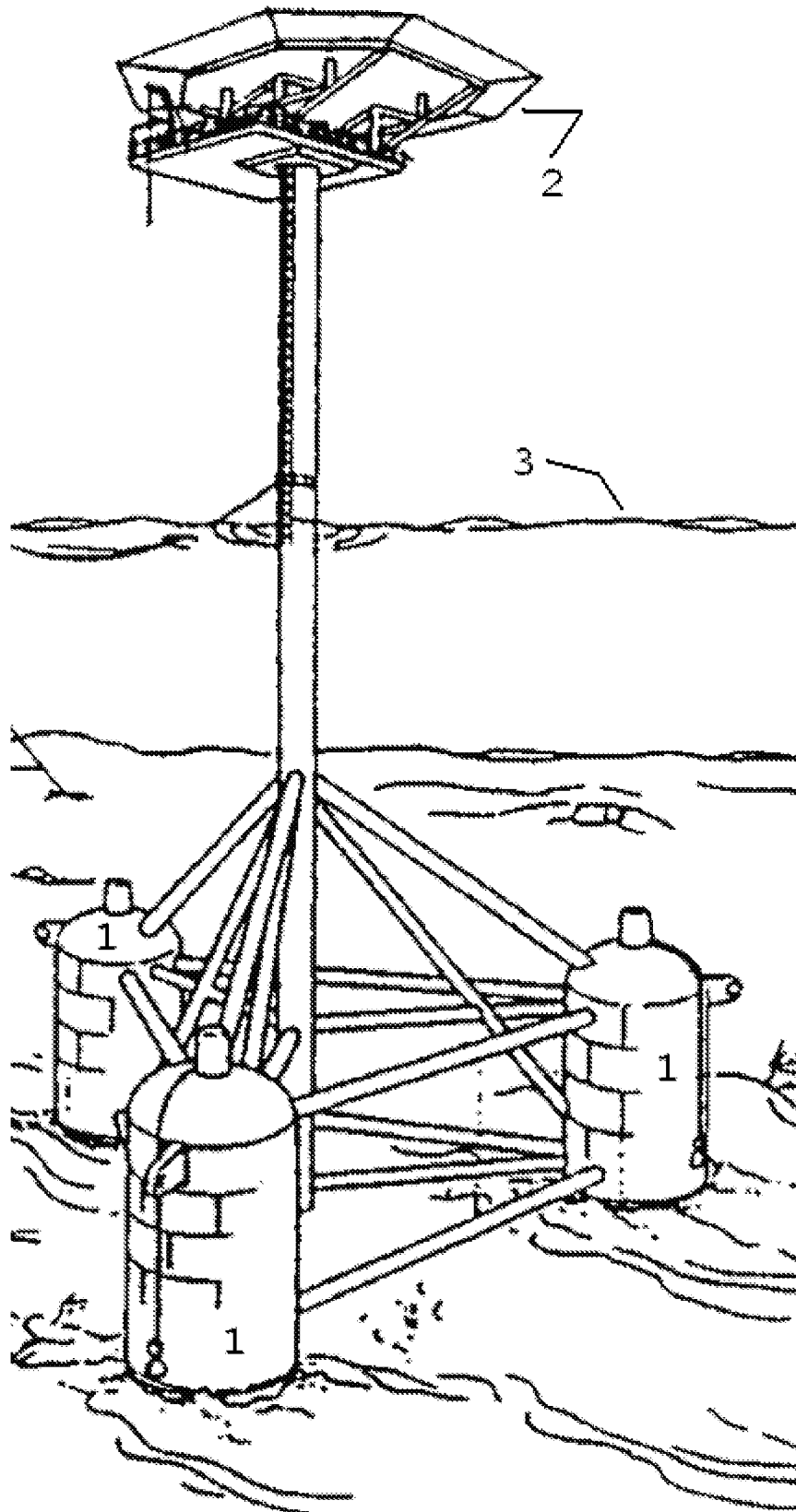


Fig. 14

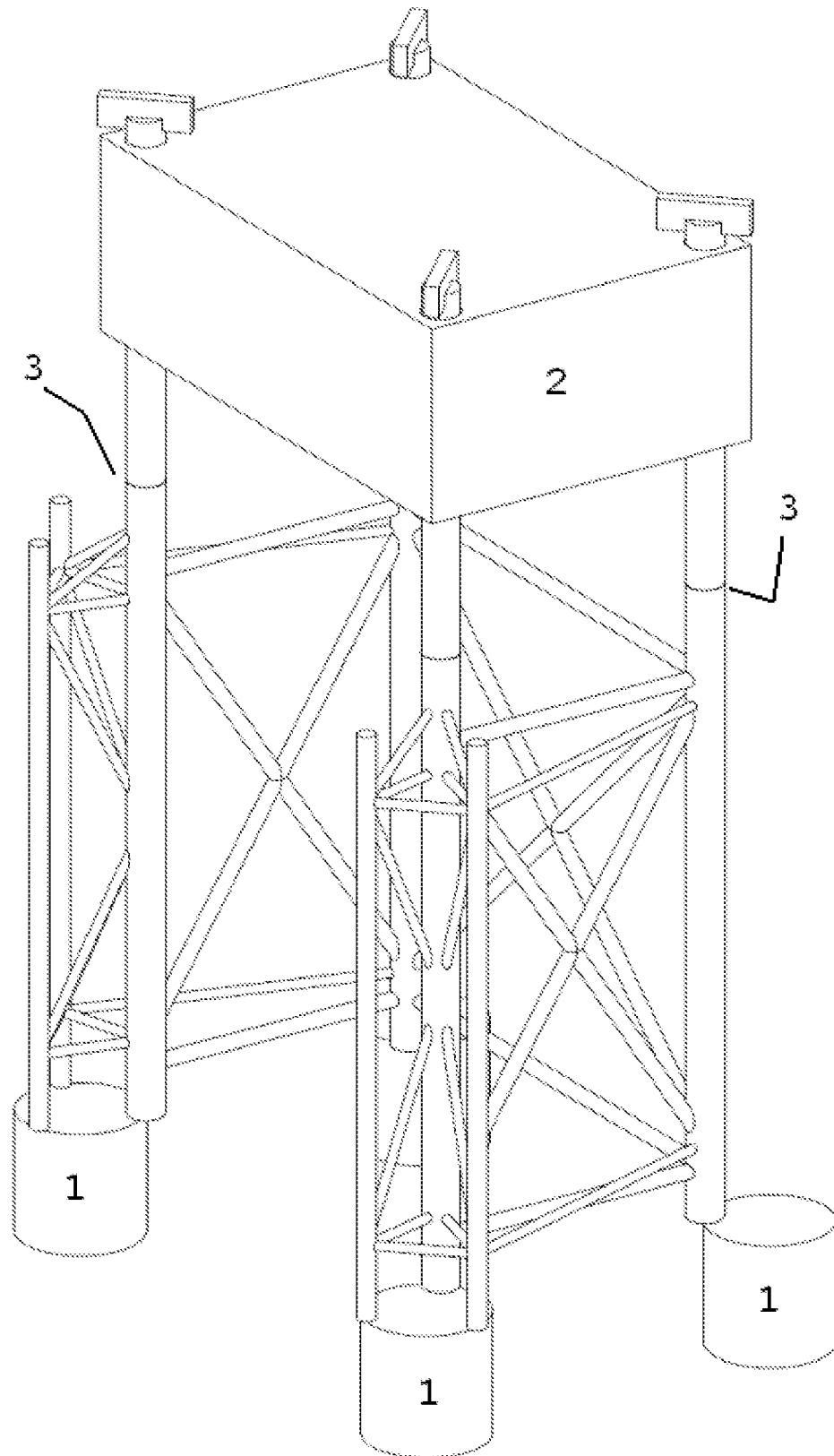


Fig. 15

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- GB 2300661 B [0002]
- EP 0011894 B [0002]
- WO 9951821 A [0003]
- EP 1101872 A [0003]
- WO 02088475 A [0003]
- US 8025463 B [0004]
- WO 03099646 A [0005]