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

(11) EP 3 222 783 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
27.09.2017 Bulletin 2017/39

(51) Int Cl.:
E02D 27/52 *(2006.01)*

(21) Application number: **17162940.5**

(22) Date of filing: **24.03.2017**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(30) Priority: **24.03.2016 NL 2016485**
23.03.2017 NL 2018568

(71) Applicant: **SPT Equipment BV**
3447 GW Woerden (NL)

(72) Inventor: **Riemers, Mark**
3447 GW Woerden (NL)

(74) Representative: **Assendelft, Jacobus H.W.**
Assendelfts Octrooibureau
Keukenhofdreef 20
2161 AZ Lisse (NL)

(54) FLOATING MARINE STRUCTURE WITH SUCTION PILES

(57) Marine structure comprising a foundation with one or more suction piles installed in the seafloor to operate as a foundation or part of it to support an offshore structure resting onto the seafloor, the suction pile having internally below the top bulkhead a grout plug, which grout plug is fluid permeable to provide a fluid connection between the suction pile inner spaces above and below it, e.g. wherein a fluid flow channel extends through the grout plug.

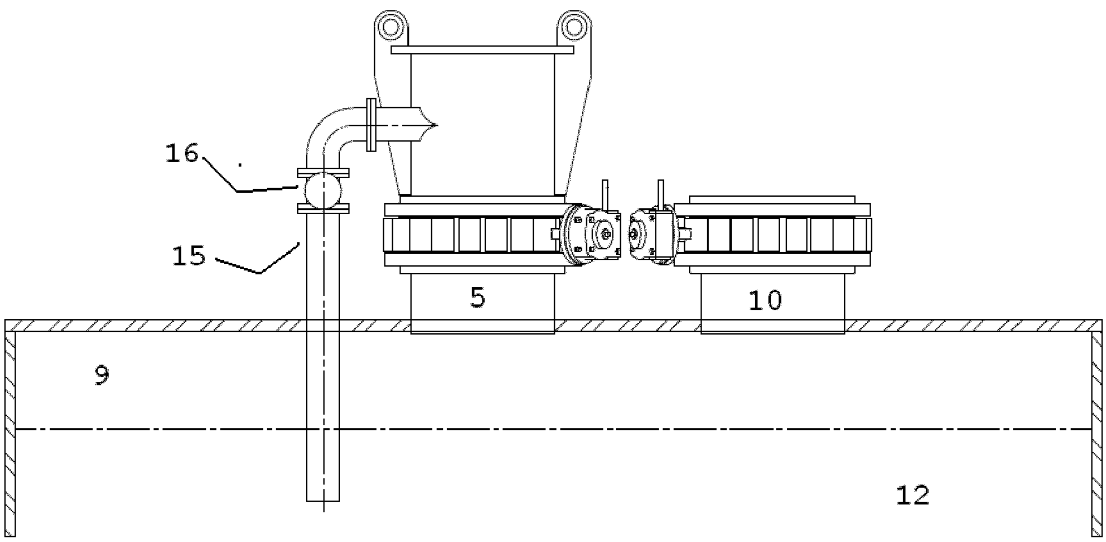

Fig. 6

EP 3 222 783 A1

Description

[0001] The invention relates to re-floating (also called recovering or retrieving or decommissioning) of a suction pile (hereafter also called "pile") and a marine structure provided with one or more suction piles as its foundation or part of it.

[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 marine structure, e.g. 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 (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 suction pile seabed anchor having within its suction space a seabed soil retainer embodied by a top down oriented cone with sharp angled apex. N2011860 (Duotop) discloses a pre-installed load bearing surface at small distance below the top bulkhead. EP1881113 (suction&dredging) discloses a straight tube extending downwards from the top bulkhead to inject water for dredging purposes.

[0006] One of the benefits of suction piles is that a marine structure can be designed to be self foundating 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 meters; a height of at least 5 meters; a wall thickness of at least 1 centimeter; 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 or eccentric.

OBJECT OF THE INVENTION

[0009] After installation into the sea bed is completed, a gap can remain between the top of a soil plug inside the suction space and the closed suction pile top. Such gap can be filled, e.g. with grout or cement concrete or a different, preferably form free, fill material (hereafter called "grout plug") which preferably cures or hardens or becomes rigid after it has entered the gap. This grout plug inside the suction space obstructs the development of an overpressure within the suction space during decommissioning. In stead of "plug", one could also name this rigid object "slab". Obviously, this slab is provided after the suction pile is sunk to the water bottom and penetrated the water soil to its final depth, by pouring or casting the at that time flowable material of the slab into the fluid filled space between the top bulkhead and the top face of the soil plug within the suction pile.

[0010] The gap to be filled with the grout plug typically has a height between 10 or 20 or 30 and 50 or 100 or 150 centimeters.

[0011] The object of the invention is versatile. In an aspect removal of the foundation is facilitated.

[0012] The object is obtained by providing the grout plug (provided after the suction pile penetrated the seafloor to its end depth) such that it is fluid (i.e. gas and/or liquid) permeable such that a fluid flow from the bottom to the top, or vice versa, of the grout plug is allowed, such that a fluid from a fluid source (e.g. pump) above the grout plug can flow through the grout plug to below the grout plug and e.g. into the soil plug below it and/or a fluid from below the grout plug, e.g. from the soil plug below it, can flow through the grout plug to a fluid drain (e.g. pump) above it. E.g. the grout plug is provided with one or more fluid channels.

[0013] The permeability or porosity can be provided prior to, during or after application of the grout plug.

[0014] Providing the fluid permeability is possible in different ways, e.g. by providing the grout plug more or less like a foam with open cells or pores distributed through its thickness such that the permeability is provided by the mutually connected cells or pores. In this manner the permeability of the grout plug is substantially equally distributed across its top and bottom surface.

[0015] In an embodiment a fluid channel is provided by a mechanical operation, e.g. drilling, through the rigid grout plug, preferably through its complete thickness such that the fluid channel debouches both at its top face and bottom face. This procedure is most likely adopted at the time when it is desired to decommission it, thus at the end of the service life of the suction pile. Subsequently, a pump is connected to the top end of this drilled fluid channel to pump a fluid from this pump through the fluid channel into the area below the grout plug to press out the suction pile.

[0016] In another embodiment a fluid channel is provided by locating near the top bulkhead a downward extending tube like element (hereafter called "tube") within the suction space at such a location that at least a length part of it becomes embedded within the grout plug. This procedure is most likely adopted at the time the grout plug is still form free or prior to or during casting the material to provide the grout plug. Most likely the suction pile is provided with such tube before the suction pile sinks to the sea bottom, e.g. on shore where the pile is manufactured. At the time of decommissioning the pile a pump is connected to the tube to pump fluid into the area below the grout plug to press out the pile. Preferably the tube is provided, e.g. sealed to the top bulkhead and sufficient long to project below the top face of the soil plug, such that it is avoided that it becomes filled with grout coming from filling with grout of the cavity below the top bulkhead and the top face of the soil plug.

[0017] The tube preferably has one or more of: is eccentrically located relative to the longitudinal axis of the suction pile, e.g. at a distance of at least 50 centimeter or 1 meter; is located at a distance from the side wall of the suction pile, e.g. at a distance of at least 50 centimeter or 1 meter; is cantilevered mounted, e.g. to the top bulkhead such that it is rigid mounted at its one end (proximal end) and unsupported along its length from the mounted proximal end to the opposite distal end located within the suction space below the top bulkhead; is straight along its complete length; extends parallel to the longitudinal axis of the suction pile; is of thin walled steel; has a wall thickness of at least 0.5 or 1 or 2 or 3 or 4 or 5 millimeters, preferably over at least 50 or 60 or 70 or 80 or 90 or 95% of its length; has a cross section that is constant for at least 80 or 90 or 95% of its length; terminates at least 0.5 or 1 or 1.5 meters above the bottom end of the suction pile; is designed to be pressed or driven or urged into the seafloor soil by lengthwise downward movement of the suction pile, preferably for at least 10 or 25 of 50 centimeters deep, e.g. has sufficient wall thickness and/or diameter relative to its length between the proximal and distal end to avoid buckling and/or has a cutting distal end to facilitate penetration of the seafloor soil at reduced driving force; an unsupported length part from the distal end towards the proximal end of at least 30 or 50 centimeters; is associated with a connector, e.g. quick connector, for temporary coupling with a suction and/or pressure pump, which connector is preferably outside the suction pile, e.g. on top of the top bulkhead (such connector is preferably designed for coupling and uncoupling of the pump by a ROV); has a fixed length; is rigid; is associated with a valve to selectively prevent and allow fluid flow through it; has an extension terminating at a distance above the top bulkhead, e.g. carrying the connector.

[0018] In yet another embodiment the circumferential wall of the tube is at least along a part of its length, preferably close to the top bulkhead, e.g. the length part adjacent the bulkhead, perforated or fluid permeable such that sea water can pass the tube wall in said part, while grout preferably not. Thus, during sucking in the sea water is sucked from the suction pile through the permeable wall. When this is finished, the grout plug is provided by supplying grout to the gap. While the gap fills with grout, the tube stays free from grout since the grout can not pass the tube wall, thus the tube stays available for future use to refloat the pile. In an embodiment, since the permeable part of the tube will be embedded in the grout plug and is thus sealed, the pressurized water supplied to the tube for pressing out the pile can not escape through the permeable part, and thus can be supplied to the soil plug below the grout plug. Passage of grout can e.g. be avoided by making the perforations small enough or by providing a small water flow from inside the tube through the permeable wall during grouting, or by providing a releasable sealing means, e.g. a sleeve sliding along the tube, to selectively seal and/or cover the permeable wall part, which sealing means is preferably provided with an actuating means, e.g. projection, e.g. flange, designed to become engaged with the soil plug, to generate the sliding movement between the released and covering position.

[0019] Typically, the grout has a specific weight substantially higher then sea water such that during grouting the grout deposits on the top face of the soil plug and the grout plug develops from below while urging the water to escape through one or more vents in the top bulkhead. This continues until the growing grout plug has reached the top bulkhead and starts escaping though the same vents.

[0020] The tube can have a length sufficient to extend beyond the top and/or bottom face of the grout plug. In an alternative the tube terminates within the grout plug remote from the top and/or bottom face of the grout plug such that one or both of its ends is sealed by material of the grout plug, which seal is broken prior to pressing out the pile, e.g. by drilling or by pressurized fluid supplied by the pump.

[0021] The fluid channel preferably provides a flow cross section equal to a circular cross section having a diameter of at least 10 or 20 or 30 centimeters and/or a length at least 10 or 20 or 30 and/or at most 80 or 100 or 150 or 200 centimeters.

[0022] The fluid channel of the invention differs from tubes of the suction pile provided for different functions and extending downward from the top bulkhead. E.g. grout injection pipes which are angled and project only a small distance from the top bulkhead. Or water injection pipes having an internal diameter of only 5 centimeters and extend the complete height of the suction pile (adjacent the circumferential suction pile wall to be supported by it along their complete length) to debouch at the lower edge of the suction pile to fluidise the soil during penetration of the soil by the pile. Or a pipe for dredging purposes (e.g. EP1881113) to remove the soil plug. These kind of pipes become damaged if forced to penetrate the seafloor soil since they are not designed for such loads.

[0023] In case the tube has a water permeable part of its circumferential wall or the grout plug is water permeable for its complete thickness or the tube branches from another tube, a single fluid port with associated coupling at the bulkhead is sufficient for temporarily coupling of first the suction pump and later the pressure pump. In the alternative, the bulkhead is associated with two or more fluid ports with associated coupling, the one for temporary coupling of the suction pump, the other for temporary coupling of the pressure pump.

[0024] 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.

[0025] It is noted that the invention is preferably directed to suction piles for foundations, in other words designed to carry the weight of an upper structure, e.g. wind turbine or platform, 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 grout plug 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 desires location by trying to pull the anchoring suction pile out of the subsea bottom.

[0026] Preferably one or more of the following applies: the suction required to penetrate the suction pile into the subsea bottom during installation and/or the overpressure to extract the suction pile from the sea bed is generated within the suction pile above the grout plug or above the top bulkhead of the suction pile, preferably since the suction side of a suction pump means or the pressure side of a pressure pump means is connected to the suction pile at a location above the grout plug, e.g. the top bulkhead is provided with a nozzle or different sealable port for fluid connection of the suction space with a suction or pressure 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 grout plug obtains, by application of the invention, an increase of 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 grout plug allows free passage of fluid between above and below the grout plug; the grout plug completely fills the gap; with the penetration of the suction pile into the sea floor completed, the top bulkhead is spaced from the sea floor and/or the lower side of the grout plug 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; the by releasable sealing means, e.g. a valve, selectively closable port in the top bulkhead to allow water entering and/or exiting the suction pile is provided with a coupling means designed for temporary engagement of a suction and/or pressure pump at the time of installing and removing, respectively, of the suction pile into and from, respectively, the seafloor soil, which port is associated with the fluid flow channel.

[0027] Preferably, the design of the suction pile is such that fluid from a source, e.g. pressure pump, flows from the source through a sealed channel, comprising the permeable part of the grout plug (e.g. provided by the tube), terminating below the grout plug. The pump typically is designed to be temporary connected to the internal space (also called suction space) of the suction pile to generate an over pressure or under pressure within the suction space, preferably wherein the pressure difference generated relative to the surrounding water pressure (e.g. approximately 10 bar at 100 meter water depth or 100 bar at 1000 meter water depth) is at least 0.5 or 1 or 2 or 3 or 5 bar. Preferably the pump system is designed to generate within the suction space an over or under pressure between 5 and 10 bar. It will be appreciated that for the under pressure (i.e. the suction), lowering of the pressure within the suction space is limited by the vacuum level (0 bar) such that at a pressure of e.g. 3 bar of the surrounding water (at a water depth of approximately 20 meter), a pump system rated for 5 bar pressure difference shall be unable to lower the pressure for more then 3 bar within the suction space (in practise the maximum attainable under pressure level will be a fraction of 1 bar above vacuum, e.g. 0.1 or 0.05 bar).

[0028] 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.

[0029] The quick connector or quick release coupling can comprise one or more of: a flanged coupling in that the to be coupled longitudinal ends of two tubes each have a flange which mutually bear in the coupled state; a releasable locking means, e.g. comprising a retractable locking member, e.g. pivoting claw or finger, to positively keep the mutually coupled tubes together, e.g. a retractable pivoting finger or claw at the one tube engaging behind a hooking edge, e.g. part of a flange, at the other tube, retractable snapping hooks engaging a recess; drive means associated with the locking means, e.g. to move a locking member between a releasing retracted position and a locking extended position. Typically, the tube associated with the suction pile comprises the passive part of the locking means, e.g. hooking edge, while the tube associated with the pump comprises the active part, e.g. pivoting or differently moving retractable locking member.

[0030] The invention is directed, in an embodiment, to 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, near its top end, with a fixedly located plug, e.g. grout plug, provided after the suction pile reached the seafloor, and wherein, in use, the grout plug bottom bears onto a top of a soil plug inside the suction space, the top bulkhead of the suction pile bears onto the grout plug and a fluid flow channel extends upwardly through the grout plug to bring fluid pressure from high to low level of the grout plug, or vice versa.

[0031] 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. 2-4 show a top view, a sectional side view and a partly cut open perspective view of an embodiment of the suction pile;

Fig. 5-9 show a sectional side view of five different embodiments of the invention;

Fig. 10 and 11 show marine structures in perspective view.

[0032] 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 and is provided by the lower side of a grout plug. The top bulkhead 6 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.

[0033] Fig. 2-4 show the suction pile of fig. 1 in the completely installed stage (right hand stage of fig. 1) more in detail. The rigid grout plug 9 provides 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. The distance between the top bulkhead and the load bearing surface 4 measures 50 centimeter, thus the grout plug is 50 centimeter thick.

[0034] The pipe studs 5, 10 are located at a distance from the longitudinal axis 14 and the side wall 7 of the suction pile.

[0035] The pipe stud 5 is used during installing the pile. A similar pipe stud 10 connects to a vertical pipe 15. The lower end of pipe 15 terminates below the lower face 4 of the grout plug 9 and penetrates the soil plug 12. In this manner a source of pressurized fluid connected to pipe stud 10 can supply pressurized fluid at a level below grout plug 9, such that an overpressure will be generated within the soil plug 12 within the suction pile, forcing the suction pile upward. Obviously, fluid flow through pipe stud 10 will be made impossible during installing the pile, and through pipe stud 5 during removing the pile. Fig. 7 shows an alternative based on the provision of dedicated ports 5, 10 for installing and removing, respectively, of the pile.

[0036] Fig. 5 shows an embodiment without pipe stud 10 and pipe 15. A drill shaft (indicated by the arrow) is inserted in pipe stud 5 to drill a vertical channel through the rigid grout plug and subsequently pressurized fluid is supplied via pipe stud 5 to flow through the drilled channel and into the soil plug 12 to press out the pile. Pipe stud 5 is provided with a coupling above the top bulkhead, designed for temporary engagement of both a suction pump and a pressure pump, which pumps are only present during sucking at the time of installing in and pressing out at the time of recovering of the suction pile, respectively.

[0037] According to fig. 6, the vertical pipe 15 is designed as a bypass or branch and connects to pipe stud 5, such that an additional pipe stud 10 is superfluous. Pipe 15 is provided with a valve 16 such that during installation no water is sucked through pipe 15. Pipe stud 10 is in this case a vent to allow air to escape during sinking of the pile. Selectively closable pipe stud 5 is provided with a coupling above the top bulkhead, designed for temporary engagement of both a suction pump and a pressure pump, which pumps are only present during sucking at the time of installing in and pressing out at the time of recovering of the suction pile, respectively. Pipe stud 10 needs not such coupling since it is merely a selectively closable vent.

[0038] Fig. 7 is similar to fig. 3. Selectively closable pipe stud 5 and also selectively closable pipe stud 10 are provided with a coupling above the top bulkhead, designed for temporary engagement of a suction pump (in case of pipe stud 5) and a pressure pump (in case of pipe stud 10), which pumps are only present during sucking at the time of installing in and pressing out at the time of recovering of the suction pile, respectively.

[0039] Fig. 8 shows an embodiment having a water permeable, but grout impermeable, tube 15 such that both a suction pump and a pressure pump can be connected to pipe stud 5 to install and remove, respectively, the suction pile. The permeability is only provided in the circumferential wall part immediately below the top bulkhead. Thus, as soon as the distal end (the lower end) of the tube 15 has reached the soil plug and thus becomes sealed, the water flow into the pipe stud 5 due to the connected suction pump (not shown) develops according to the arrows at high level in the drawing of fig. 8. During pressing out the permeable part of tube 15 is sealed by the grout plug, thus the water flow into the suction pile due to the to the pipe stud 5 connected pressure pump (not shown) develops according to the arrows at low level in the drawing of fig. 8.

[0040] In the alternative, the embodiment of fig. 8 could be provided with increased porosity such that grout could also penetrate the tube wall. Increased porosity is beneficial for increased water through put such that sucking in proceeds quicker. To avoid ingress of grout, a water impermeable sleeve 17 (shown in phantom in fig. 8) is provided around the tube 15 as a selective sealing means. The sleeve is provided with a flange as an actuating means. Initially, the sleeve 17 is at the lower or distal end of the tube and the porous area of the tube 15 is at higher level and thus allows free flow of water through the tube wall. When sucking in is almost completed, the flange engages the soil plug 12 and thus the soil plug 12 moves the sleeve 17 upward along the tube 15 to cover, and thus seal, the porous wall part of the tube 15, to avoid ingress of grout. It is not required that this seal is water tight since a small gap between sleeve 17 and tube 15, indeed allowing water from inside the suction pile to be sucked into the tube 15, is already sufficient to avoid grout entering the tube during grouting since during grouting no water is sucked to the tube from inside the suction pile.

[0041] Fig. 9 shows an alternative to the fig. 6 embodiment.

[0042] For both embodiments of fig. 8 and 9, selectively closable pipe stud 5 is provided with a coupling above the top bulkhead, designed for temporary engagement of both a suction pump and a pressure pump, which pumps are only present during sucking at the time of installing in and pressing out at the time of recovering of the suction pile, respectively.

[0043] Fig. 10 and 11 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.

[0044] 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 drawing, the specification and claims contain many features in combination. The skilled person will consider these also individually and combine them to further embodiments. Features of different in here disclosed embodiments can in different manners be combined and different aspects of some features are regarded mutually exchangeable. All described or in the drawing disclosed features provide as such or in arbitrary combination the subject matter of the invention, also independent from their arrangement in the claims or their referral.

Claims

1. Marine structure comprising a foundation with one or more suction piles installed in the seafloor to operate as a foundation or part of it to support an offshore structure resting onto the seafloor, the suction pile having internally near the top bulkhead and spaced from this bulkhead preferably a fixed load bearing surface designed to keep the suction pile immovable while the offshore structure resting onto it is in full operation, which load bearing surface is provided by an initially form free fill material, e.g. a grout plug, which is supplied into the suction pile at its final location and/or while present within the suction pile at its final location is hardened or cured or has become rigid in another manner.

2. Structure according to claim 1 and which load bearing surface and/or grout plug is fluid permeable to provide a fluid connection between the suction pile inner spaces above and below it.

3. Structure according to claim 1 or 2, wherein a fluid flow channel extends through the grout plug.

4. Structure according to claim 1, 2 or 3, the load bearing surface is at least 10 or 20 or 50 centimeter and/or 1 or 1.5 or 2 meter to a maximum below the top bulkhead.

5. Structure according to any of claims 1-4, the suction pile being a prefabricated object comprising the fluid flow channel and preferably not the grout plug.

6. Structure according to any of claims 1-5, wherein the fluid flow channel extends downward from the top bulkhead and/or extends a vertical distance of at least 50 centimeters or at least 1 or 2 meters.

7. Suction pile for a structure according to any of claims 1-6.

8. Method of installing a structure according to any of claims 1-6, or a suction pile according to claim 7, 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 after penetration is completed the load bearing surface is provided by applying initially form free fill material, e.g. grout to provide the, preferably rigid, plug within the suction pile, such that finally the load bearing surface bears onto the seafloor and the top bulkhead of the suction pile bears onto the plug, preventing continuation of further penetration.

9. Method according to claim 8, wherein at the end of the method but prior to application of the grout plug the top bulk head is at a level above the sea floor, preferably at least 10 or 20 or 50 centimeter and/or 1 or 1.5 or 2 meter to a maximum, and preferably the space within the suction pile below the top bulkhead and above the sea floor is substantially vacant of rigid elements.

10. Method according to claim 8 or 9, wherein, while the suction pile progressively penetrates the seafloor, a fluid flow channel extending from the top bulkhead downwards penetrates the seafloor, preferably after the suction pile bottom has penetrated the seafloor for at least 1 or 2 or 3 meters, and at the time of refloating a pressurized fluid is supplied to the fluid flow channel from outside the suction pile, preferably from its top.

11. Method according to any of claims 8-10, wherein pressurized fluid is supplied, through the fluid channel, from above the grout plug to below the grout plug to press out the pile.

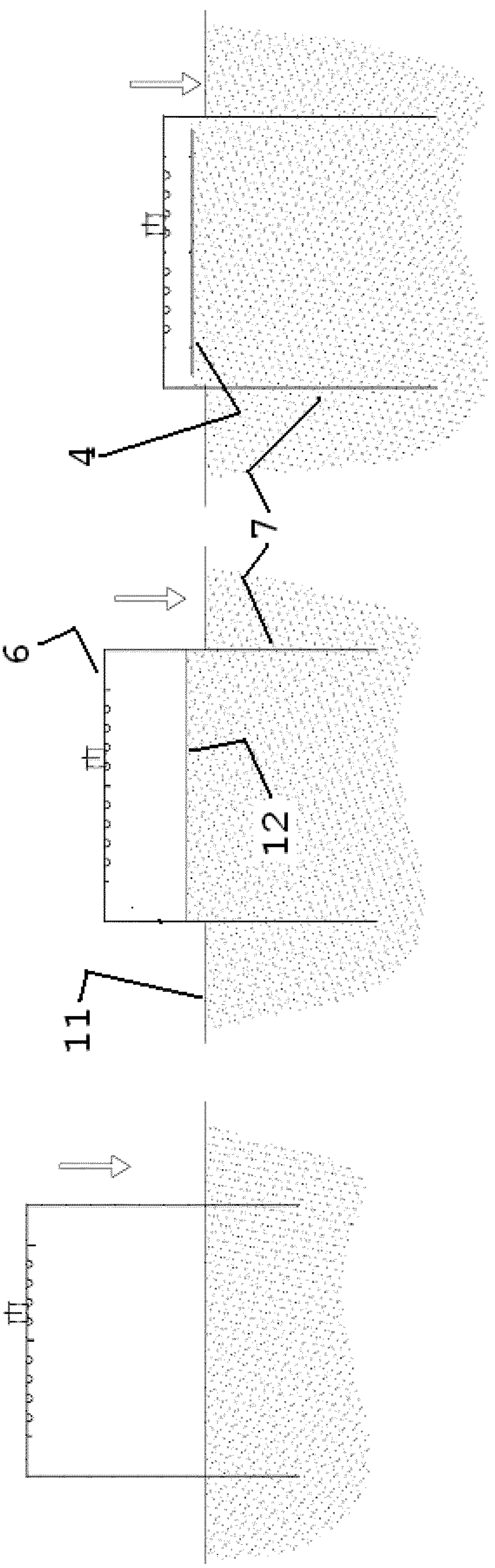

Fig.1

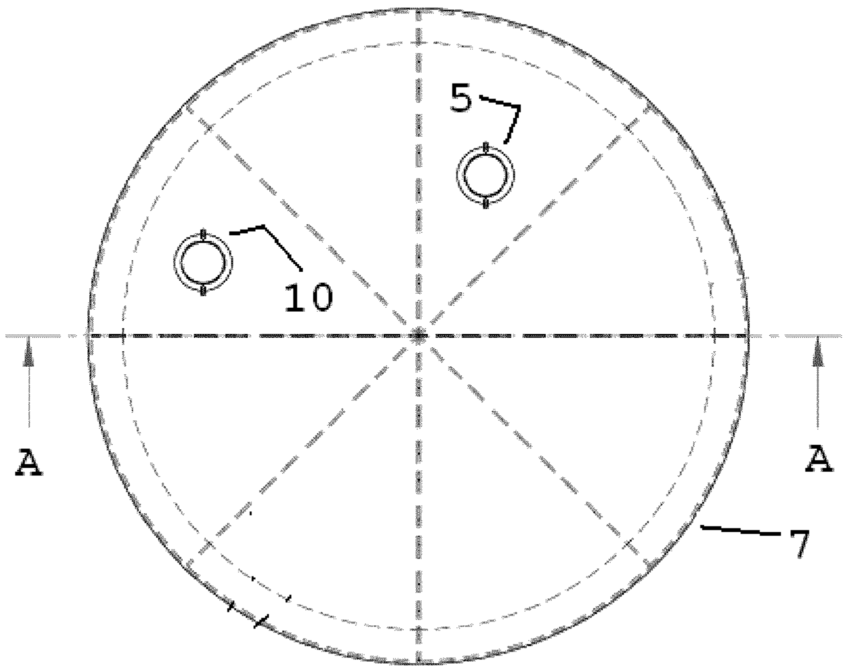

Fig.2

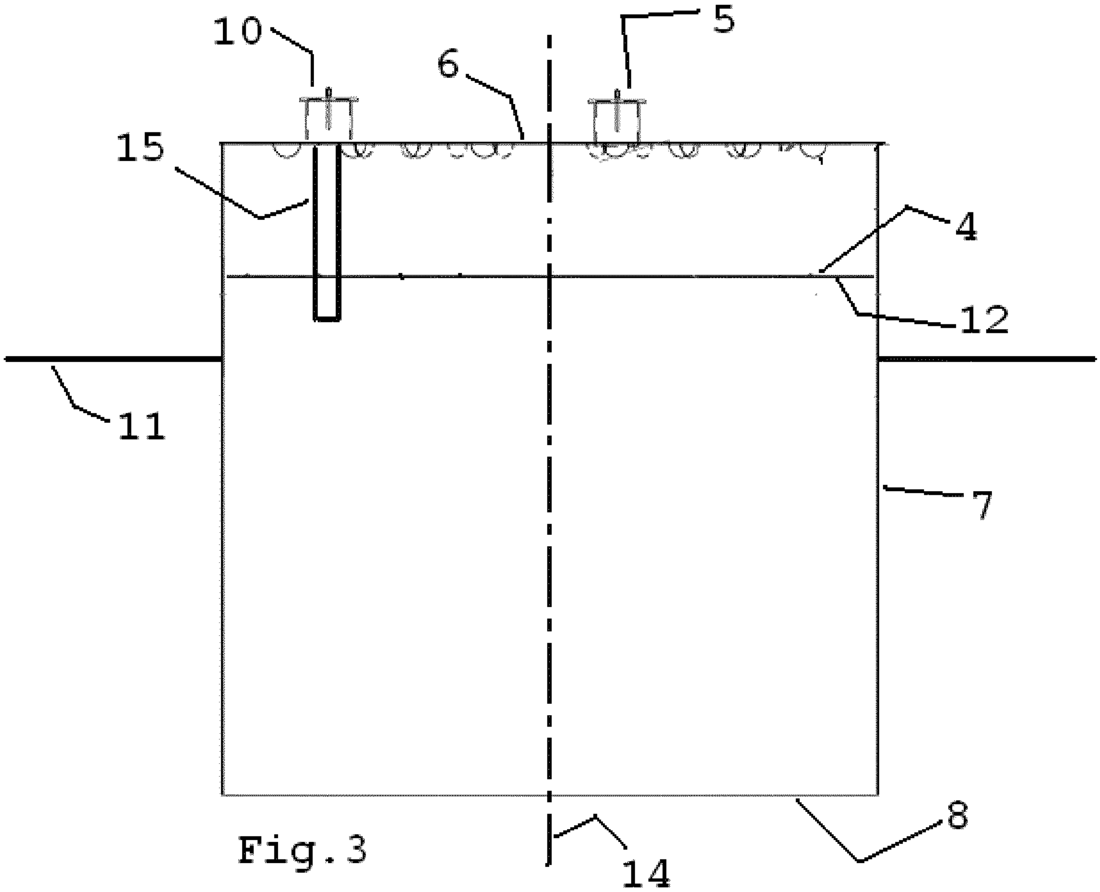

Fig.3

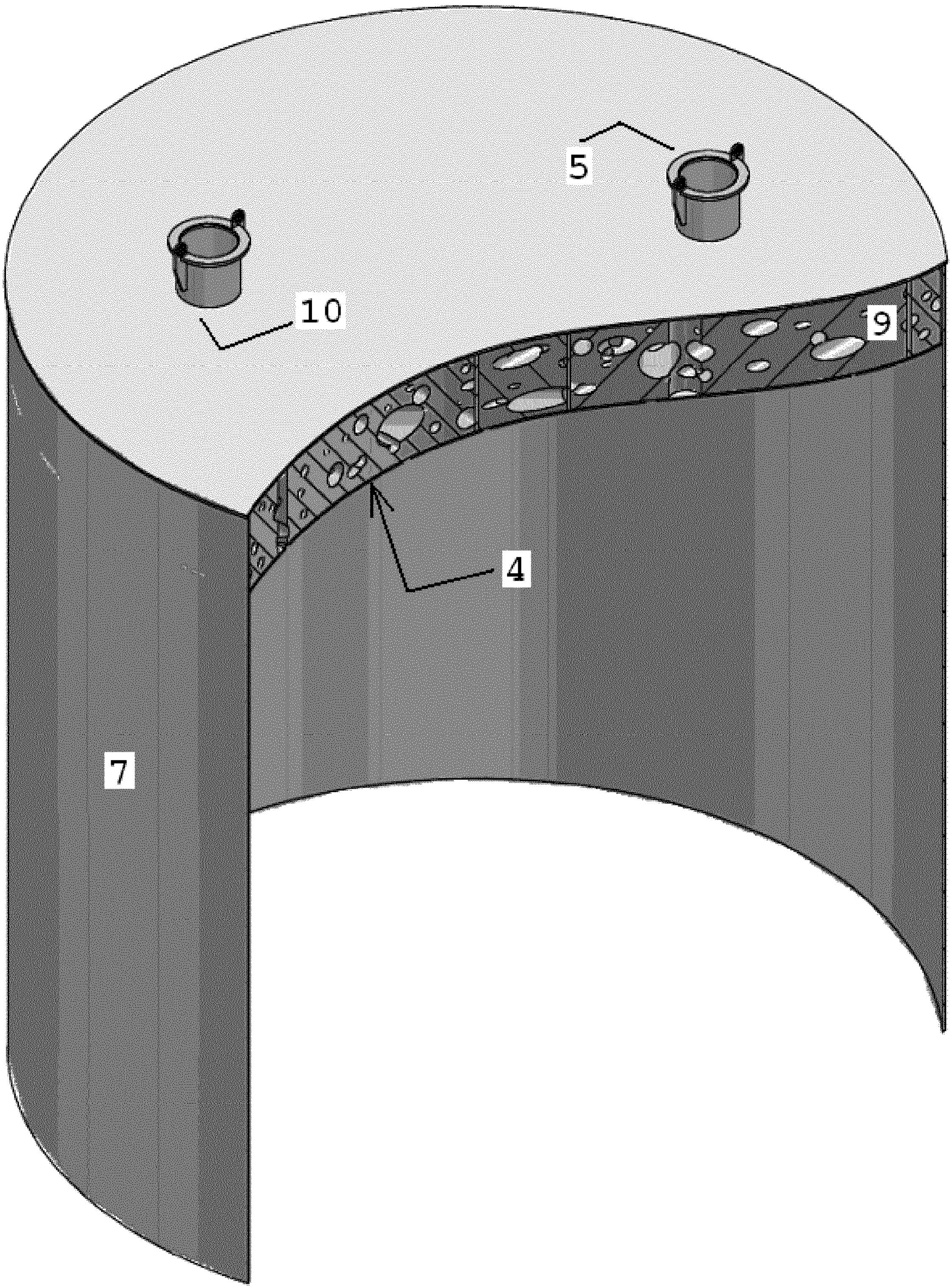

Fig. 4

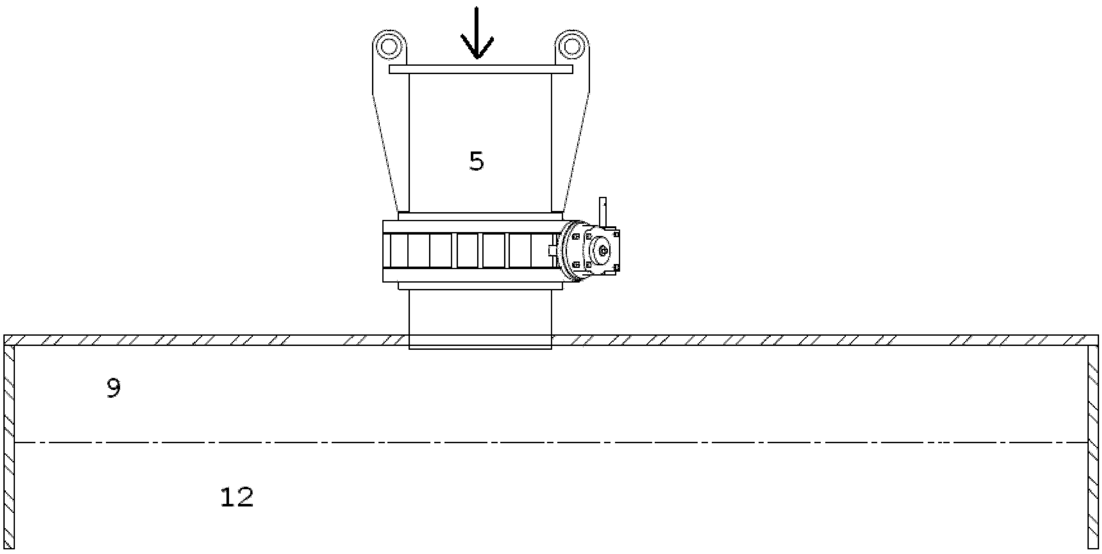

Fig. 5

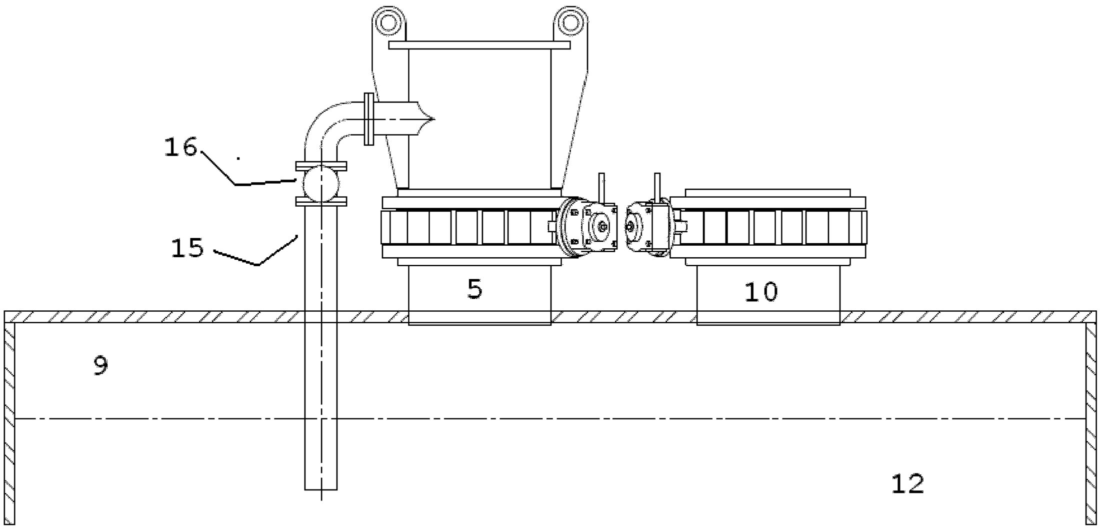

Fig. 6

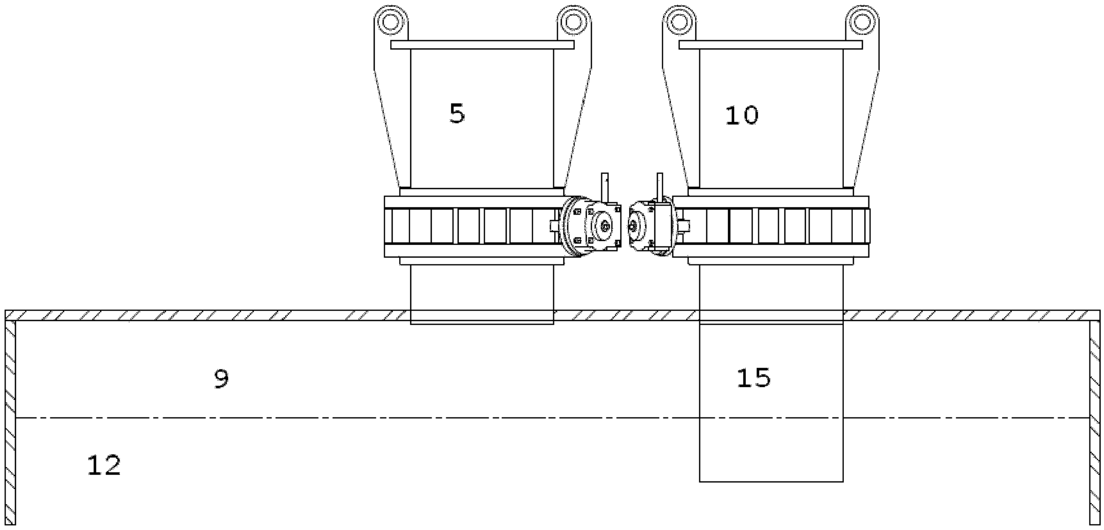

Fig. 7

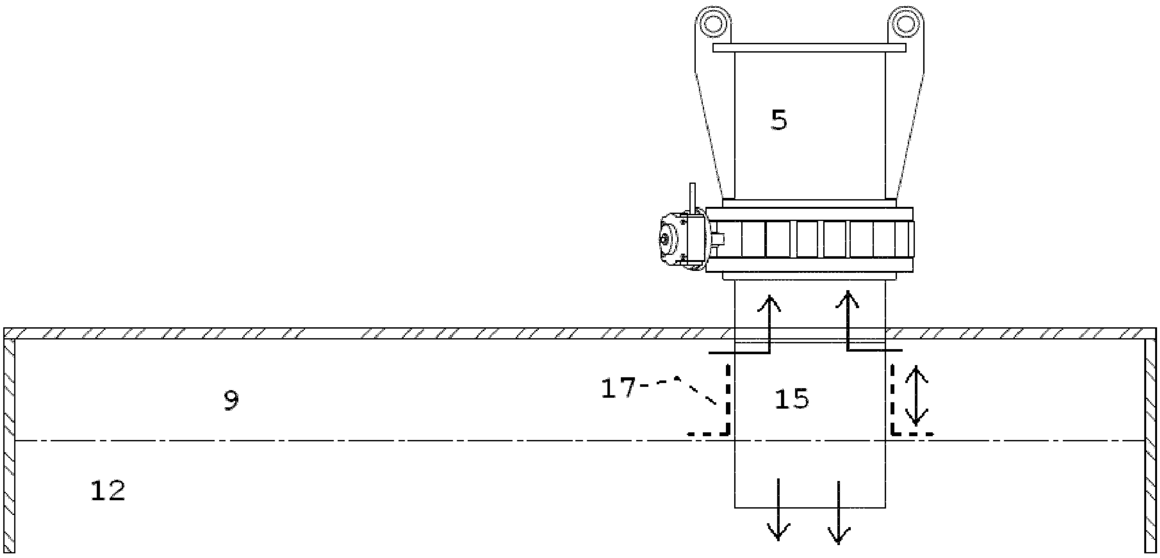

Fig. 8

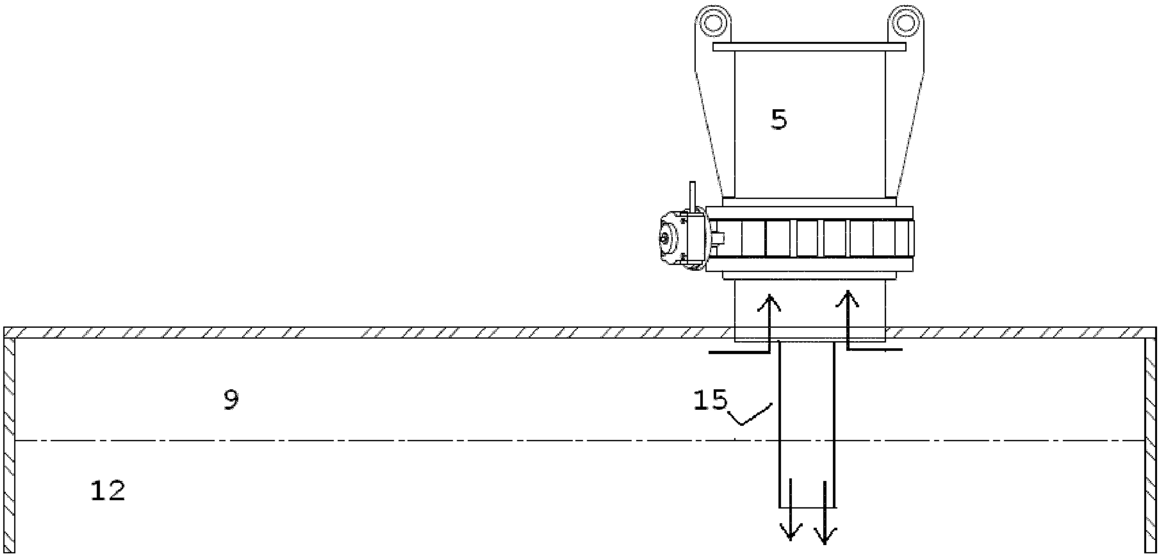

Fig. 9

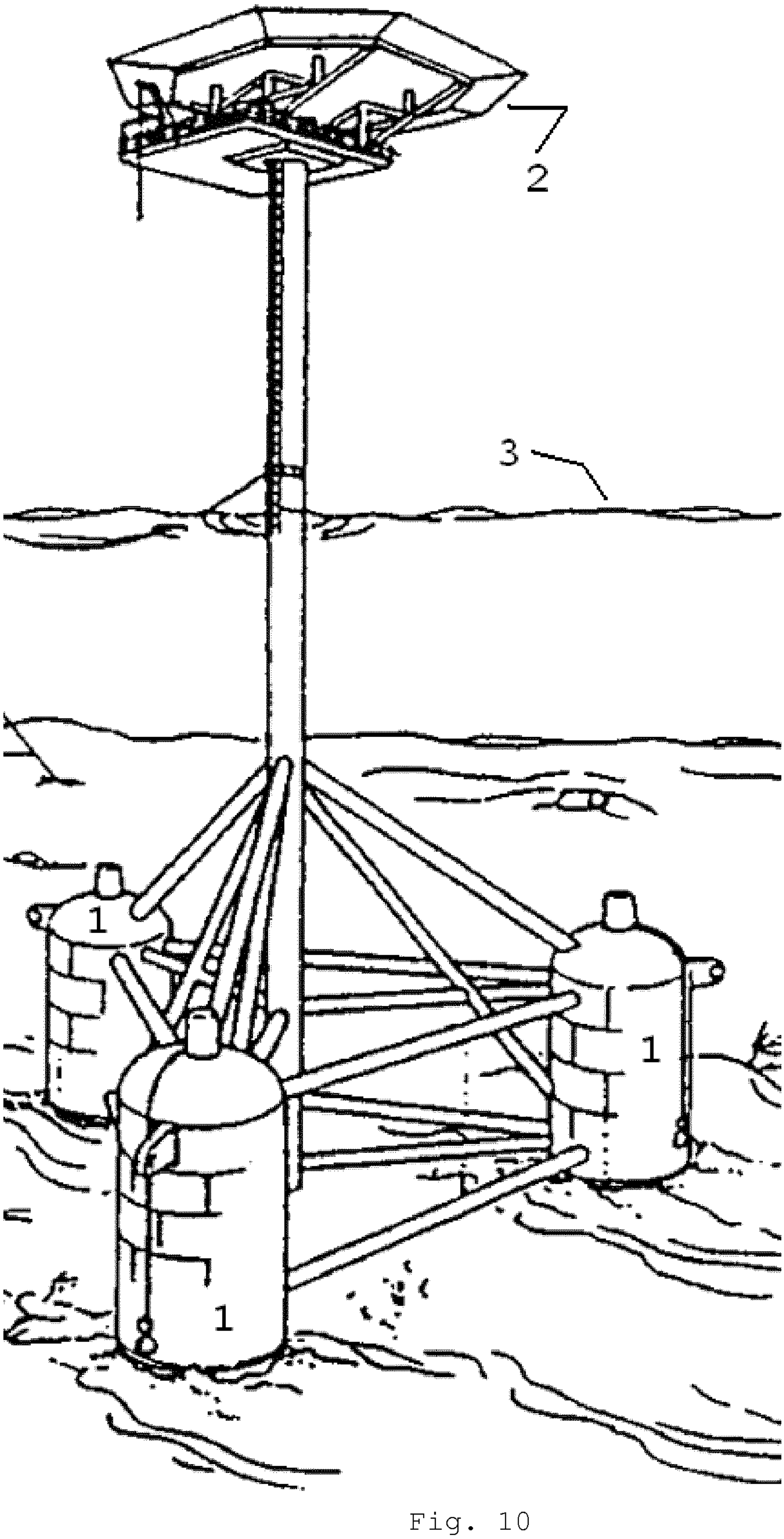

Fig. 10

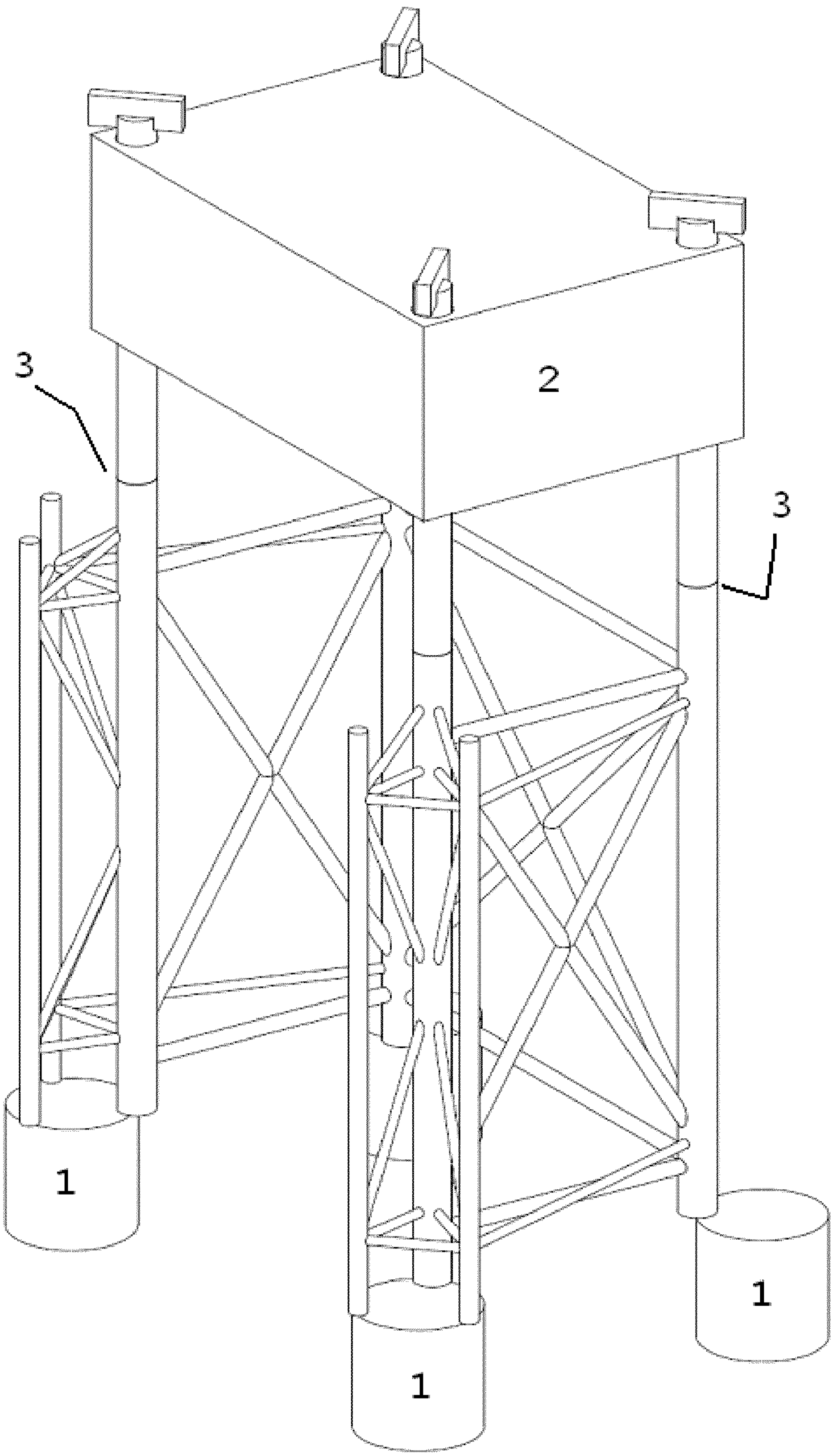

Fig. 11

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 17 16 2940

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X A	WO 2014/084737 A1 (DIJKSTRA OENE JELJER; SUCTION PILE TECHNOLOGY BV [NL]) 5 June 2014 (2014-06-05) * abstract * * page 3, lines 5-35 * * page 4, lines 23-31 * * page 6, line 31 - page 8, line 15; figures 1-15 * -----	1-9,11 10	INV. E02D27/52

TECHNICAL FIELDS SEARCHED (IPC)
E02D B63B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	24 July 2017	Koulo, G

CATEGORY OF CITED DOCUMENTS

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

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

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 17 16 2940

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

24-07-2017

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2014084737 A1	05-06-2014	EP 2925936 A1	07-10-2015
		WO 2014084737 A1	05-06-2014

EPO FORM P0459

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

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

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]**
- EP 1881113 A **[0005] [0022]**