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(54) **Method for providing a foundation for a mass located at height, and a positioning frame for performing the method**

(57) The invention relates to an efficient method for providing a foundation for a mass located at height, such as the jacket of a wind turbine or a jetty, wherein the foundation comprises a number of piles (40) driven into a bottom in a geometric pattern. The method comprises of providing a floating device (60) provided with lifting means (18); providing a positioning frame (1) comprising a number of mutually connected guide sleeves (2a,2b, 2c,2d) arranged in a geometric pattern for the purpose of receiving the piles; lowering the positioning frame to the bottom (30) into a position of use via the lifting means (18); and arranging the piles in the bottom through the guide sleeves of the positioning frame in the position of use, and to a positioning frame (1) adapted to perform the method.

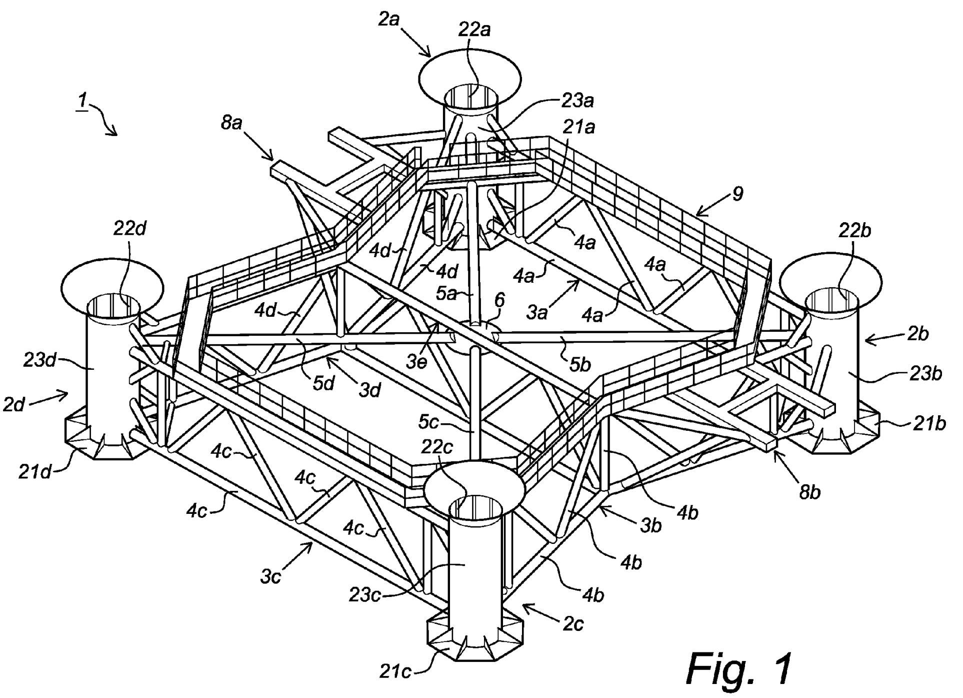

Fig. 1

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Description

[0001] The invention relates to a method for providing a foundation for a mass located at height, such as the jacket of a wind turbine or a jetty, wherein the foundation comprises a quantity of piles driven into a bottom in a geometric pattern. The invention also relates to a positioning frame adapted to perform the method.

[0002] The invention will be elucidated hereinbelow with reference to an offshore wind turbine. The reference to a wind turbine in no way implies that the invention is limited to the use in the context of such a wind turbine. The positioning frame and the method can likewise be applied on any other structure, such as jetties, radar and other towers, platforms and the like. The support structure of a wind turbine normally has a slender design, for instance in the form of a tube or pillar. This pillar structure has to be coupled to a foundation in the bottom. For offshore wind turbines, which are placed in relatively shallow water, it is possible to make use of one mast extending from the machinery housing of the wind turbine to the foundation. In addition to such a mono-pole construction, the support structure of an offshore wind turbine can also comprise a tubular upper part and a lower part in the form of a lattice structure, also referred to as a jacket. A large part of the jacket extends underwater, where the jacket finds support on a bottom, in many cases the underwater bottom.

[0003] A known method for providing a foundation for a mass located at height, such as the jacket of a wind turbine, comprises of providing an offshore platform in the vicinity of the location provided for the foundation, determining the location for each pile, subsequently manipulating each pile using a lifting crane present on the platform and driving each pile into the bottom. Once all the piles have been arranged in the bottom in the desired geometric pattern, thus forming the foundation, the jacket is arranged on the foundation formed by the quantity of piles by arranging legs of the jacket in the piles (also referred to as pin piling) or, in an alternative method, around the piles (also referred to as sleeve piling). The piles are adapted in both cases to be able to receive the legs of the jacket, for instance by providing hollow piles (pin piling) or hollow legs of the jacket (sleeve piling).

[0004] The above described operations of the known method are time-consuming and can in a typical case take at least 5 to 7 days.

[0005] The invention has for its object to provide a method for providing a foundation for a mass located at height which is more efficient than the known method, i.e. takes less time than the known method.

[0006] This object is achieved according to the invention by a method comprising of:

- providing a floating device provided with lifting means;
- providing a positioning frame comprising a number of mutually connected guide sleeves arranged in a geometric pattern for the purpose of receiving the piles;
- lowering the positioning frame to the bottom into a position of use via the lifting means;
and
- arranging the piles in the bottom through the guide sleeves of the positioning frame in the position of use.

[0007] The method according to the invention allows a foundation to be provided in the form of a number of piles arranged in a geometric pattern in less time than known heretofore. Once the positioning frame has been placed in the correct position (in relation to the anticipated position of the quantity of piles), it requires no further repositioning as is often necessary in the prior art because the positioning frame, due to its own weight, causes friction with the bottom, and more particularly via base plates (21a, 21b, 21c) arranged on the underside of the positioning frame. Because the positioning frame is placed into the position of use via the lifting means, and these lifting means can be chosen in accordance with the requirements and conditions on site, an optimum positioning of the frame is possible.

[0008] The positioning frame is brought into the position of use by lowering the frame via the lifting means. The position of the frame in the position of use is not determined particularly accurately here, for instance in view of the often rough conditions at sea. An embodiment of the method according to the invention therefore comprises of positioning and/or orienting the positioning frame to the position of use by means of separate positioning means. Such positioning means allow displacement of the positioning frame in its entirety to the desired position of use. The positioning means are adapted here such that they enable at least translations of the positioning frame relative to the bottom surface, particularly in a plane running more or less parallel to the bottom surface (referred to below as a horizontal plane), and preferably also rotations relative to the bottom surface. Rotations of the frame relative to the bottom surface can here comprise rotations around an axis running substantially perpendicularly of the bottom surface, but also rotations around an axis lying in a horizontal plane or in a plane varying from a horizontal plane. The method according to the invention makes it possible to increase the accuracy of positioning of the positioning frame relative to the bottom (and so also relative to the desired positions of the foundation piles) to variations in the horizontal plane of a maximum of 10 cm, preferably a maximum of 5 cm. This accuracy is unprecedented for a structure with the dimensions of a positioning frame and provides a great advantage because, due to the more accurate positioning of the positioning frame, a more accurate positioning of all foundation piles to be provided in the bottom is also achieved in one operation.

[0009] In an embodiment of the method and device which is simple, and for this reason reliable, the positioning means are adapted only to displace the positioning frame in a horizontal plane and to rotate it about an axis running substantially perpendicularly of this plane.

[0010] It is possible to position and/or orient the positioning frame by moving the frame along the spud poles of a jack-up platform. Because the position of the positioning frame is determined by the position of the platform, and this latter is not greatly affected by current and wind forces, this is also the case for the positioning frame. The use of the positioning frame also allows accurate positioning of the quantity of piles in only one operation. The position of use of the positioning frame corresponds to a position in which the positioning frame, and in particular the guide sleeves thereof, is ready to receive the piles. The position of use is preferably located at a position in the vicinity of the bottom, and more preferably at a position in which the positioning frame substantially rests on the bottom.

[0011] The positioning frame can be moved along and under the guidance of the spud poles by any means known to the skilled person. It is thus possible for instance to suspend the positioning frame from a number of traction cables, wherein the cables can be varied in length by for instance winches arranged on the work deck of the platform. The cable length can be shortened or lengthened using the winches, wherein the positioning frame is respectively lifted or lowered. In a preferred embodiment of the method according to the invention the positioning frame is further provided with means for guiding the positioning frame along the spud poles of an offshore platform from a high position in the immediate vicinity of the work deck of the platform to a lower position, optionally onto or into the immediate vicinity of the bottom. The guide means are preferably adapted such that they can guide the positioning frame along the spud poles of the platform so that the positioning frame is aligned substantially horizontally in the lower position. This can for instance take place by suspending the positioning frame by means of three, and preferably by means of four cables, wherein each cable can be varied in length independently of the other cables by winches. This is particularly important in the case of a bottom which is not wholly flat.

[0012] The positioning frame according to the invention preferably comprises a lattice structure with a number of guide sleeves which are disposed spaced apart at the corner points thereof and which are connected by tubular lattice elements. The dimensions of the positioning frame in the plane are in principle larger than the dimensions out of the plane, wherein the direction out of the plane corresponds to a direction parallel to the lifting or lowering direction of the positioning frame. The guide sleeves are adapted to receive and guide the piles for driving into the bottom, and preferably comprise cylindrical casings, the longitudinal axis of which runs parallel to the direction of the positioning frame out of the plane. The guide sleeves are arranged in a geometric pattern, this pattern corresponding to the desired geometric pattern of the foundation piles. The tubular lattice elements extending between the guide sleeves ensure that guide sleeves remain substantially in their position during lifting and lowering of the positioning frame. In the present embodiment the positioning frame is adapted to define a specific geometric pattern of the foundation piles. It is however also possible to make the positioning frame geometrically adaptable, for instance by providing the positioning frame with lattice elements adjustable in length and/or by providing the positioning frame with nodes which mutually connect lattice elements and allow adjustment of the angle between lattice elements. Such an embodiment allows realization of different geometric patterns of the foundation piles.

[0013] Although making use of the spud poles of a platform as positioning means for the positioning frame has certain advantages, a further positioning is no longer possible in the position of use, except in the height.

[0014] In an embodiment according to the invention a method is provided in which the positioning frame is positioned and/or oriented by engaging the frame with a remotely operated robot vehicle (ROV). A more flexible positioning can be achieved with this embodiment of the method.

[0015] A more accurate positioning is achieved in yet another embodiment according to the invention which provides a method in which the positioning frame is positioned and/or oriented by engaging the frame with traction cables provided with anchors, and/or an embodiment which provides a method in which the positioning frame is positioned and/or oriented by providing the frame with an assembly of manoeuvrable thrusters. Suitable are for instance azimuth thrusters comprising a propeller accommodated in a housing. The housing is rotatable here so that the positioning frame can be oriented during displacement and displaced in this orientation. If desired, use can also be made of a rudder or other steering gear for orienting purposes.

[0016] In the embodiment in which anchors and traction cables are applied, a number of traction cables are connected on one side to the positioning frame and connected on the other side by means of the anchors to the bottom or other anchoring point. The positioning frame can be displaced relative to the anchoring points by changing the free length of the traction cables, for instance by means of winches.

[0017] The above stated embodiments all have the advantage that the positioning of the positioning frame relative to the bottom can take place independently of the platform, which enables corrections of the position, wherein translations in the horizontal plane and possible rotations of the positioning frame relative to the underwater bottom are all possible.

[0018] A preferred embodiment of the method according to the invention comprises of establishing the position of at least one pile and positioning the positioning frame such that at least one of the guide sleeves of the positioning frame is aligned with the position of the pile, in other words is located directly above said pile position.

The arranging of a first pile through the at least one guide sleeve fixes the positioning frame. In such a position the guide sleeves for the other piles will automatically be located in their correct positions because their relative positions are determined by the geometric design of the positioning frame. A position determination for each individual pile is hereby no longer necessary.

[0019] The guide sleeves of the positioning frame are adapted to receive and guide piles when they are carried into the bottom. In order to be able to receive the piles the guide sleeves preferably have a diameter which is at least as large as the cross-section of the piles. In order to enable adequate support of the piles use is preferably made of guide sleeves, the inner surface of which is provided along at least a portion of the length of the guide sleeves with support ribs for the piles. In order to enable easy removal of the positioning frame once the piles have been arranged in the bottom, the piles are preferably driven so far through the guide sleeves that the top of the piles extends further than the underside of said portion (provided with support ribs) of the length of the guide sleeves.

[0020] The method according to the invention is preferably **characterized in that** the foundation piles are arranged in the bottom by being driven into the bottom by the action of hydraulic or pneumatic hammer devices, vibrating hammer devices and/or oscillators. Such devices can be disposed on the floating device or on another floating device located in the vicinity. More preferred is a method in which the piles are driven into the bottom further than said portion (provided with support ribs) by the follower of a pneumatic hammer. A pneumatic hammer with follower is per se known to the skilled person.

[0021] Another embodiment of the invention relates to a method in which the arranging of the piles in the bottom is performed by drilling the foundation piles, and/or shafts in which the foundation piles are arranged, into the underwater bottom by means of drilling means.

[0022] In yet another embodiment of the method according to the invention the drilling is performed by means of reverse circulation drilling (figure 15) by pre-drilling with a casing (figure 14) and/or by rock-socketing.

[0023] In another aspect of the invention a method is provided comprising the step of removing the positioning frame once the piles have been arranged in the bottom, wherein the removal of the positioning frame is performed by lifting thereof with guiding by the spud poles from the lower position to the high position in the vicinity of the work deck of the platform.

[0024] The invention further relates to a method for installing on a foundation a mass located at height, such as the jacket of a wind turbine or a jetty, wherein the foundation comprises a number of piles arranged by means of the above described method in a bottom, the method comprising of arranging legs of the mass located at height into or around the piles. A method is more preferably provided comprising of anchoring the legs to the piles by means of grouting.

[0025] Although the method according to the invention can be applied to provide a foundation of the above described type, the method is preferably applied on a bottom located underwater.

[0026] The method according to the invention is further particularly suitable for cylindrical (hollow) foundation piles with a length of more than 20 m, more preferably at least 25 m and most preferably at least 30 m, and a weight of 20 to 150 tonnes, more preferably of 40 to 130 tonnes and most preferably of 50 to 110 tonnes.

[0027] The guide sleeves preferably have a height (the dimension in the longitudinal direction of the guide sleeves) of at least 1 m, more preferably at least 3 m and most preferably at least 5 m, in order to further be able to guarantee the desired guiding function and vertical alignment of the foundation piles.

[0028] In yet another aspect of the invention a positioning frame is provided, which frame is adapted to provide a foundation for a mass located at height, such as the jacket of a wind turbine or a jetty, wherein the foundation comprises a number of piles driven into a bottom in a geometric pattern, which positioning frame comprises a number of mutually connected guide sleeves arranged in a geometric pattern and adapted to receive and guide a pile to be driven into the bottom, in addition to means for positioning and/or orienting the positioning frame, the means comprising an assembly of manoeuvrable thrusters.

[0029] The invention will now be elucidated in more detail with reference to the drawings, without otherwise being limited thereto. In the figures:

Fig. 1 shows a schematic perspective view of an embodiment of the positioning frame as applied in the method according to the invention;

Fig. 2 shows a schematic perspective view of an embodiment of the jack-up platform adapted to be used in the method according to the invention;

Fig. 3-7 show schematic side views of a number of embodiments of method steps for lowering the positioning frame;

Fig. 8-13 show schematic side views of a number of embodiments of method steps for arranging the piles in the bottom through the guide sleeves of the positioning frame in the position of use;

Fig. 14 shows a schematic side view of a drilling device applied in an embodiment of the method according to the invention;

Fig. 15 shows a schematic side view of a rotating drill head equipped with nozzles of a drilling device applied in an embodiment of the method according to the invention; and

Fig. 16 shows schematically a jacket of a wind turbine placed according to the invention on a foundation of piles.

[0030] Shown with reference to figure 1 is a device according to the invention in the form of a positioning frame 1 which comprises at the corner points four cylindrical guide sleeves (2a, 2b, 2c, 2d) adapted to receive and guide a pile. Guide sleeves (2a, 2b, 2c, 2d) are rigidly connected to each other by side lattices (3a, 3b, 3c, 3d) which are constructed from a relatively large number of tubular structural elements (4a, 4b, 4c, 4d). Cross braces (5a, 5b, 5c, 5d) connect the side lattices (3a, 3b, 3c, 3d) to a central connecting plate 6, whereby the lattice gains structural stiffness. Additional lattice elements, such as as frame 3e, can be added in order to build up sufficient stiffness. All elements (2, 3, 4, 5) and connecting plate 6 define the positioning frame 1. The upper parts of side lattices (3a, 3b, 3c, 3d) are advantageously provided with a peripheral catwalk 9 for easy access and inspection. Guide sleeves (2a, 2b, 2c, 2d) are held in a fixed position relative to each other by the side lattices (3a, 3b, 3c, 3d) and the cross braces (5a, 5b, 5c, 5d), this such that guide sleeves (2a, 2b, 2c, 2d) are arranged in a geometric pattern, this pattern being in the embodiment shown in figure 1 a square with a side of about 20 m. Any other geometric pattern is however possible, such as a triangular pattern for instance.

[0031] Each guide sleeve (2a, 2b, 2c, 2d) comprises a cylindrical peripheral wall (23a, 23b, 23c, 23d) which is supported by a base plate (21a, 21b, 21c, 21d) and with which positioning frame 1 can find support on the bottom. The inner surface of each guide sleeve (2a, 2b, 2c, 2d) is provided along a portion of the length of the guide sleeve with support ribs (22a, 22b, 22c, 22d) for supporting a pile when it moves through the guide sleeve. The dimensions of guide sleeves (2a, 2b, 2c, 2d) can be selected within wide limits, but have in the shown embodiment a height of about 6 m. Support ribs (22a, 22b, 22c, 22d) extend through a distance of about 3 m as measured from the upper edge of guide sleeves (2a, 2b, 2c, 2d), whereby the lower portion of the inner surface is without support ribs over about 3 m (and so has a larger diameter).

[0032] Positioning frame 1 can further be provided with means for guiding positioning frame 1 along the spud poles of an offshore platform shown in figure 2. In the embodiment shown in figure 1 these means comprise a structure with two U-shaped end forks (8a, 8b) which are fixedly connected to the rest of positioning frame 1 by means of tubular elements. Positioning frame 1 is positioned relative to platform 10 such that a spud pole (13a, 13b, 13c, 13d) of platform 10 is partially received in the space between the outer legs (9a, 10a, 9b, 10b) of the U-shaped end forks (8a, 8b), the space being large enough to be able to receive a spud pole. Positioning frame 1 can in this way be guided downward and/or upward along the spud pole(s). The means for guiding the positioning frame 1 along spud poles (13a, 13b, 13c, 13d) of the platform also comprise lifting means, such as winches 15 provided on the work deck of platform 10.

[0033] A jack-up platform 10 adapted according to the invention is shown in figure 2. For reasons of clarity a number of structures, such as a lifting crane 18 (see figures 3-9), normally present on a jack-up platform are omitted from the figure. Jack-up platform 10 comprises substantially a work deck 11 and four spud pole jacks (12a, 12b, 12c, 12d) at the corner points of work deck 11. Each jack (12a, 12b, 12c, 12d) operates a spud pole (13a, 13b, 13c, 13d) which can be lowered in the vertical direction 14 until the relevant spud pole finds support on bottom 30 (figure 6). Work deck 11 is provided with winches 15 over which run cables which are connected to positioning frame 1. Using winches 15 the positioning frame 1 can be raised or lowered in the vertical direction 14. Platform 10 is further provided with two circular openings or moon pools (16a, 16b) which provide access to the water present under work deck 11 and which have a diameter which is large enough for passage of a foundation pile. Platform 10 thus carries the positioning frame 1, which in the shown preferred embodiment is provided on the underside of platform 10 in a rest position in the immediate vicinity of work deck 11 of platform 10. The assembly of platform 10 and positioning frame 1 is positioned such that moon pool 16b is vertically aligned with guide sleeve 2c, indicated in figure 2 with broken line 17.

[0034] The above described embodiment can advantageously be applied in the invented method, but a number of other preferred embodiments are nevertheless described below which have other or more advantages in determined aspects.

[0035] Referring to figure 3 for instance, an embodiment of the method according to the invention is shown, which method is characterized by providing a floating device 60 provided with lifting means in the form of lifting crane 18. Floating device 60 can for instance comprise a vessel, a platform, a pontoon or number of pontoons, and may or may not be independently driven. Positioning frame 1 with the shown mutually connected guide sleeves (2b, 2c) arranged in a geometric pattern is lowered via lifting crane 18 and hoisting cables 61 onto the underwater bottom 30 into a position of use in which the frame 1 finds stable support due to the relatively wide base plates (21a, 21b, 2 1 c, 2 1 d) and its own weight. Figure 4 shows another embodiment in which floating device 60 comprises a platform 10 which supports by means of shown spud poles (13b, 13c) on the underwater bottom. Positioning frame 1 is lowered via lifting crane 18 and hoisting cables 61 onto the underwater bottom 30 into the position of use, wherein the lowering of positioning frame 1 therefore takes place independently of the spud poles. Referring to figure 5, yet another embodiment is shown in which positioning frame 1 is positioned and/or oriented by engaging the frame 1 with a remotely operated robot vehicle 62, also referred to as a Remote Operated Vehicle or ROV, provided with a drive 63 and manipulators 64 which can engage on parts of positioning frame 1.

[0036] Referring to figure 6, yet another embodiment is shown in which positioning frame 1 is positioned and/or oriented by engaging the frame 1 with traction cables 66 which are provided with anchors 65 and connected to positioning frame 1. By anchoring the traction cables 66 in the bottom 30 using anchors 65 the frame 1 can be accurately positioned by taking in and/or paying out the traction cables 66 by means of winches 15. Positioning frame 1 can be guided here along the spud poles of platform 10 as well as independently of the spud poles.

[0037] Yet another highly advantageous embodiment is shown in figure 7. Positioning frame 1 is positioned and/or oriented here by providing frame 1 with an assembly of manoeuvrable thrusters 67 which are able to drive positioning frame 1 in a chosen direction, this depending on the direction in which the manoeuvrable thrusters 67 are oriented. Positioning frame 1 can be guided here along the spud poles of platform 10 as well as independently of the spud poles.

[0038] Once positioning frame 1 has been positioned on underwater bottom 30 as according to the above described embodiments, foundation piles 40 are arranged in bottom 30 through guide sleeves (2a, 2b, 2c, 2d) of positioning frame 1 in the position of use.

[0039] A possible embodiment is shown in figure 8. It is noted that in the shown embodiment positioning frame 1 is situated in front of spud pole 13b of platform 10, therefore separately of platform 10, and has thus been lowered independently of the spud poles onto bottom 30, has particularly been positioned by one of the other above described methods, preferably by means of a positioning frame 1 provided with thrusters. As shown, a pile lining tube 41 can be picked up by lifting crane 18 and placed in moon pool 16b of the platform above the desired position 33 of the first pile. Should position 33 be located adjacently of the platform, this step is then not necessary.

[0040] In a subsequent step of the method (see figure 9) a pile 40 is picked up by lifting crane 18 from a storage rack 42 located on platform 10 and lowered until the underside of pile 40 is situated at the level 43, this level being close to the level of the bottom (see figure 10).

[0041] Once pile 40 has been correctly aligned with guide sleeve 2c, the pile is lowered further until it is partially received in tube 2c. The pile is then carried further under its own weight into the underwater bottom 30, during which process the pile is guided through guide sleeve 2c as shown in figure 10. As shown in figure 12, pile 40 is then driven into bottom 30 until the top of pile 40 has penetrated further into guide sleeve 2c than the portion provided with support ribs. Pile 40 can be driven into bottom 30 by means of a pneumatic hammer 44 as shown in figure 12, although there are other embodiments which can be equally suitable or even more suitable.

[0042] Referring to figure 13, an embodiment is shown in which the arranging of piles 40 in bottom 30 is performed by drilling the foundation piles 40, and/or shafts in which the foundation piles 40 are arranged, into the underwater bottom 30 by means of drilling means. In the shown embodiment platform 10 is provided with a crane 18 to which is attached a drill string 68 of the bottom hole assembly type. Drill string 68 is lowered by lifting crane 18 into a guide sleeve or casing 69 which has been placed in bottom 30 by an oscillator 691. This method is particularly suitable for harder bottoms 30 consisting for instance of a rock-bed 301 with a layer 302 of weathered rock thereabove. Guide casing 69 is preferably arranged as far as the rock-bed 301.

[0043] As shown in figure 14, another embodiment comprises drilling means 70 with an underwater part suspended by means of a lifting plate 75 from suspension means in the form of a cable 71. Using cable 71 drilling means 70 can be carried underwater until they come into contact with the guide sleeves, such as guide sleeve 2b, and can be connected thereto. The control of drill head 73 and the like takes place with control means 76 which are situated above water and comprise, among other parts, a power source 76a, a compressor 76b and pumps (not shown) for developing hydraulic pressure, in addition to electronics (not shown). The control means are located on a floating device, for instance pontoon 77. Drilling means 70 are electrically connected to control means 76 by means of electric cables 78. Material drilled out of the underwater bottom 30 by drill head 73 can be discharged via a discharge conduit 79 to which a discharge pipe or hose (not shown) is connected if desired.

[0044] Shown in more detail with reference to figure 15 is a preferred embodiment of the drilling means 70 for drilling a shaft 80 in underwater bottom 30. Drilling means 70 comprise a drill string 162 arranged in a guide sleeve 2. Guide sleeve 2 supports at its underside 21 on underwater bottom 30, whereby a substantially water-impermeable seal can be obtained. Guide sleeve 2 is sufficiently large to provide space for drill string 162. Drill string 162 comprises a number of drill pipes 162a mutually connected by means of flanges. The hollow drill pipes 162a together form a central cavity 86. Drill string 162 is provided on the underside with a drill head 73 with cutting tools 88, for instance in the form of cutting discs. In order to avoid outward buckling of drill string 162 during drilling, drill string 162 is preferably provided with a number of stabilizers 89 which are arranged distributed in axial direction and which support against the inner wall of guide sleeve 2. Using drive means 76 the drill string 162, and therefore drill head 73, can be set into rotation in guide sleeve 2, whereby the underwater bottom 30 is crushed by the action of cutting tools 88.

[0045] Because a water column is present in the space between the substantially coaxially disposed guide sleeve 2 and drill string 162, a pressure difference is created between the upper side and the underside of drill string 162, wherein the pressure is of course higher on the underside. Owing to this pressure difference and because guide sleeve 2 is open on the underside, so that a throughfeed is possible to cavity 86, water and dislodged bottom material flow via the underside into cavity 86. An upward flow 90 is thus maintained in cavity 86 of drill string 162, in which flow 30 dislodged bottom material is discharged to the top side of drill string 162, where it is discharged via discharge conduit 79.

[0046] In order to further facilitate the discharge of dislodged bottom material through cavity 86 of drill string 162, the shown preferred variant also comprises means for injecting air under pressure into the hollow drill string 162 at the position of drill head 73. These means comprise feed lines 84 which are arranged on drill string 162 and which are connected at the one outer end to compressor 76 and which debouch at the other outer end into cavity 86 of drill string 162 via air inlet valves 83. Air supplied under pressure through lines 84 (in the direction of arrows 82) enters flow 90 via air inlet valves 83 and thus supports the flow 90.

[0047] Drilling means 70 can be further provided with one or more nozzles (not shown) for injecting a fluid, preferably water, under pressure into underwater bottom 30 at the position of drill head 73. Drill string 162 and/or guide sleeve 2 and/or drill head 73 are provided for this purpose with conduits (not shown) for feeding the fluid to the nozzles. The nozzles are preferably mounted on drill head 73 and suitable for emitting water under a first pressure of at least 200 bar, more preferably at least 350 bar, still more preferably at least 500 bar and most preferably at least 650 bar.

[0048] The above described sequence of method steps is then repeated a number of times, depending on the desired number of foundation piles which must be arranged in bottom 30. Because guide sleeves (2a, 2b, 2c, 2d) of positioning frame 1 are automatically situated in the correct positions, all piles can be driven in efficient manner into bottom 30 without losing time in determining the position for each individual pile.

[0049] Once all piles 40 have been arranged in bottom 30, positioning frame 1 can optionally be removed. If desired, the position of piles 40 and/or the vertical position of the top of each of the piles 40 can be checked prior to removal of positioning frame 1 by optical means suitable for the purpose, such as cameras, for the purpose of checking and inspecting the whole operation.

[0050] Referring to figure 16, a jacket 150 of a wind turbine 151 can be placed on the foundation realized as described above. This can take place for instance by arranging legs 152 of jacket 150 in or around piles 40 and anchoring the legs 152 to piles 40 by means of grouting.

[0051] The method and positioning frame according to the invention allow a pile foundation to be provided in efficient manner wherein it is not necessary to displace the platform regularly for each pile, whereby much time is gained compared to the known method. The invented method is less dependent on weather conditions and requires in principle no extensive inspection operations underwater, for instance by robots and/or divers.

Claims

1. Method for providing a foundation for a mass located at height, such as the jacket of a wind turbine or a jetty, wherein the foundation comprises a number of piles arranged in a bottom in a geometric pattern, the method comprising of:

    - providing a floating device provided with lifting means;
    - providing a positioning frame comprising a number of mutually connected guide sleeves arranged in a geometric pattern for the purpose of receiving the piles;
    - lowering the positioning frame to the bottom into a position of use via the lifting means; and
    - arranging the piles in the bottom through the guide sleeves of the positioning frame in the position of use.

2. Method as claimed in claim 1, further comprising of positioning and/or orienting the positioning frame to the position of use by means of positioning means.

3. Method as claimed in claim 2, wherein the positioning means are adapted such that they enable translations of the positioning frame relative to the bottom surface.

4. Method as claimed in claim 2 or 3, wherein the positioning frame is positioned and/or oriented by engaging the frame with a remotely operated robot vehicle (ROV).

5. Method as claimed in claim 2, 3 or 4, wherein the positioning frame is positioned and/or oriented by engaging the frame with traction cables provided with anchors.

6. Method as claimed in any of the claims 2-5, wherein the positioning frame is positioned and/or oriented by providing the frame with an assembly of manoeuvrable thrusters.

7. Method as claimed in any of the foregoing claims, comprising of establishing the position of at least one pile and positioning the positioning frame such that at least one of the guide sleeves of the positioning frame is aligned with the position of the pile.

8. Method as claimed in any of the foregoing claims, wherein the inner surface of the guide sleeves is provided along at least a portion of the length of the guide sleeves with support ribs for the piles, and the piles are carried through the guide sleeves until the top of the piles extends further than the underside of said portion (provided with support ribs) of the length of the guide sleeves.

9. Method as claimed in claim 8, wherein the piles are carried further than said portion, for instance by the follower of a pneumatic hammer.

10. Method as claimed in any of the foregoing claims, wherein the arranging of the piles in the bottom is performed by driving the piles into the bottom by the action of hydraulic hammer devices, vibrating hammer devices and/or oscillators.

11. Method as claimed in any of the foregoing claims, wherein the arranging of the piles in the bottom is performed by drilling the foundation piles, and/or shafts in which the foundation piles are arranged, into the underwater bottom by means of drilling means.

12. Method as claimed in any of the foregoing claims, comprising the step of removing the positioning frame once the piles have been arranged in the bottom.

13. Method for installing on a foundation a mass located at height, such as the jacket of a wind turbine or a jetty, wherein the foundation comprises a number of piles arranged in a bottom by means of the method as claimed in any of the claims 1-14, the method comprising of arranging legs of the mass located at height into or around the piles and anchoring the legs to the piles by means of grouting.

14. Positioning frame adapted to provide a foundation for a mass located at height, such as the jacket of a wind turbine or a jetty, wherein the foundation comprises a number of piles driven into a bottom in a geometric pattern, which positioning frame comprises a number of mutually connected guide sleeves arranged in the geometric pattern and adapted to receive and guide a pile to be arranged in the bottom, in addition to means for positioning and/or orienting the positioning frame.

15. Positioning frame as claimed in claim 14, wherein the positioning means are adapted such that they enable translations of the positioning frame relative to the bottom surface.

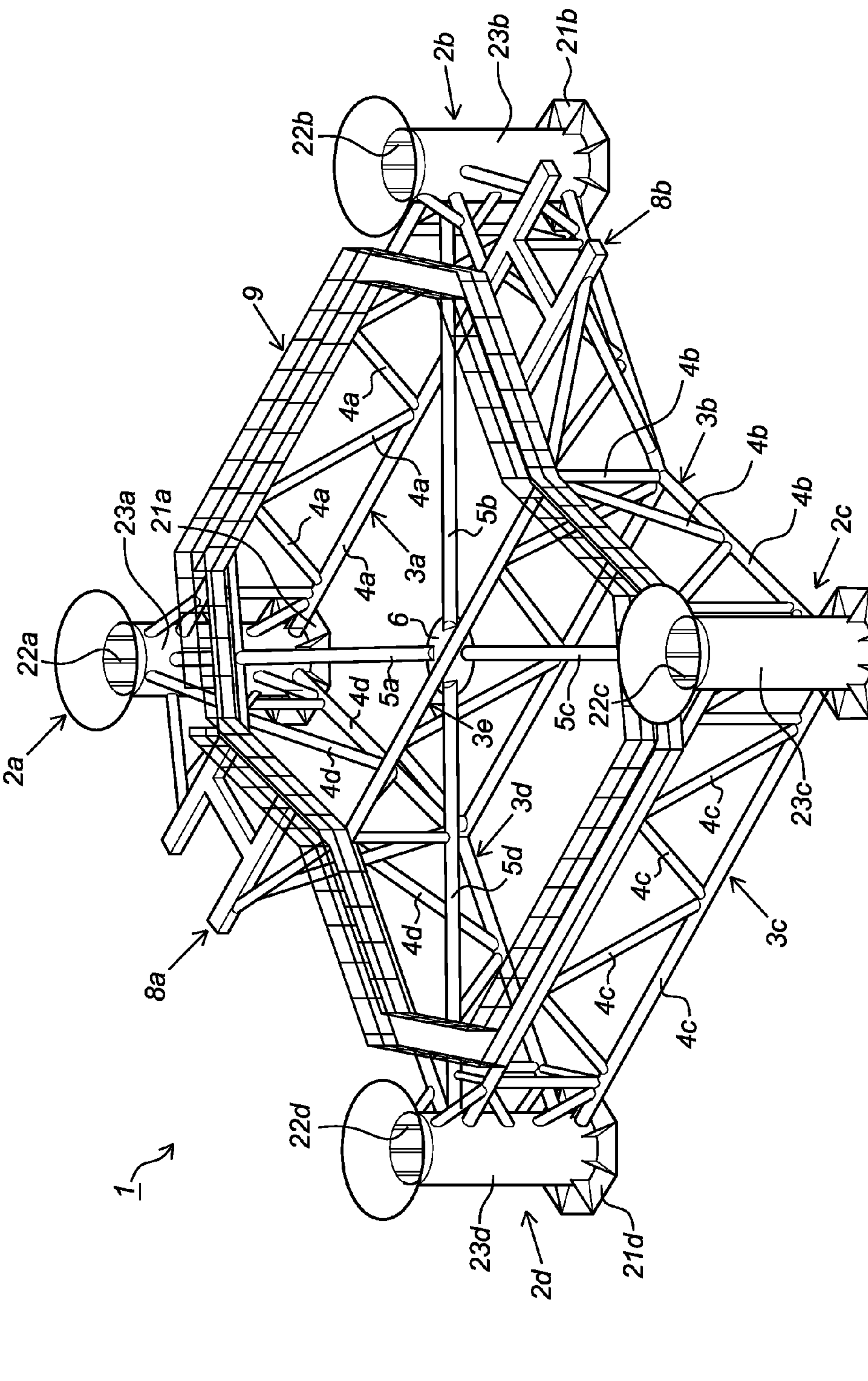
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Fig. 1

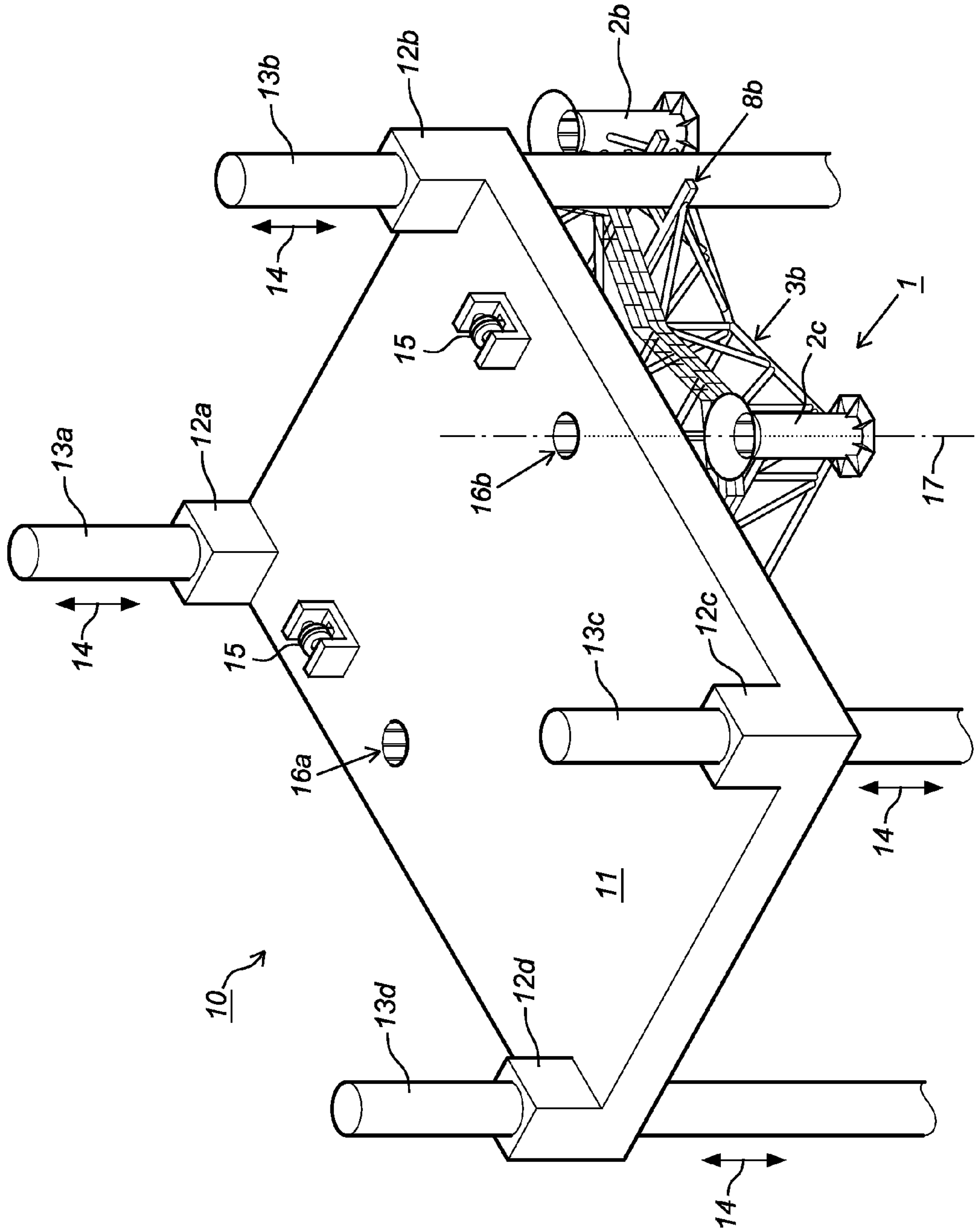
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Fig. 2

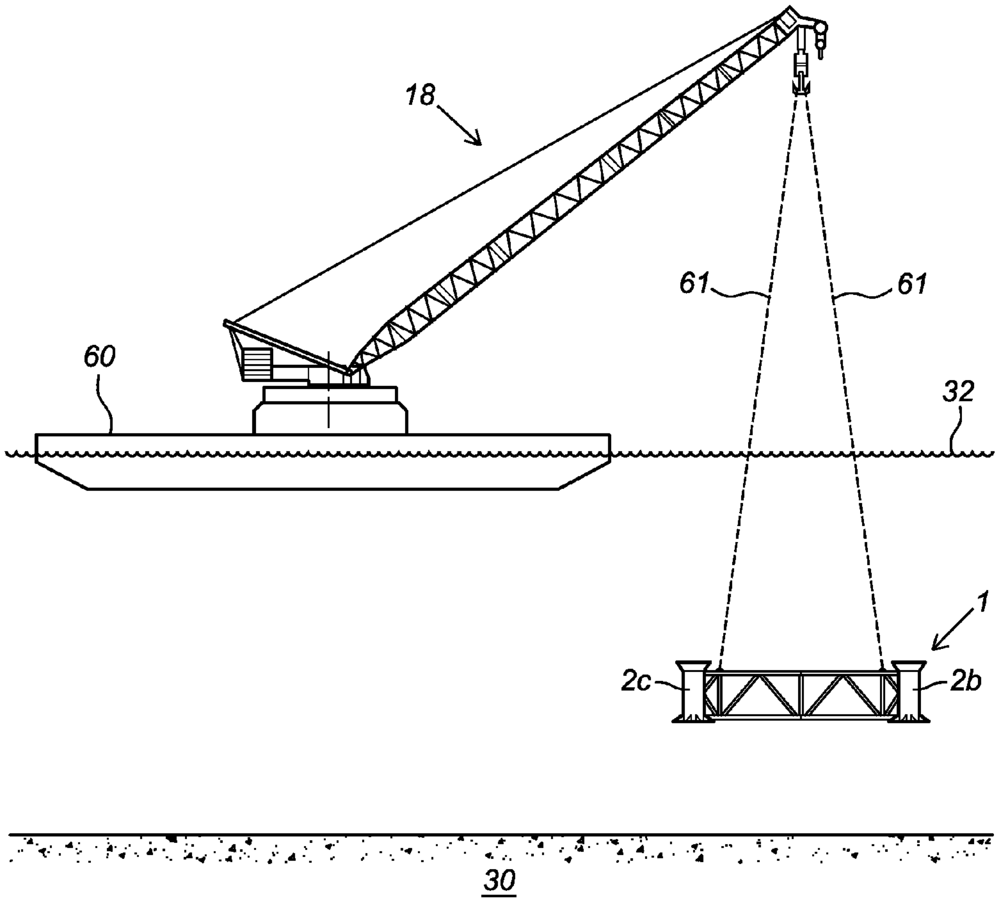
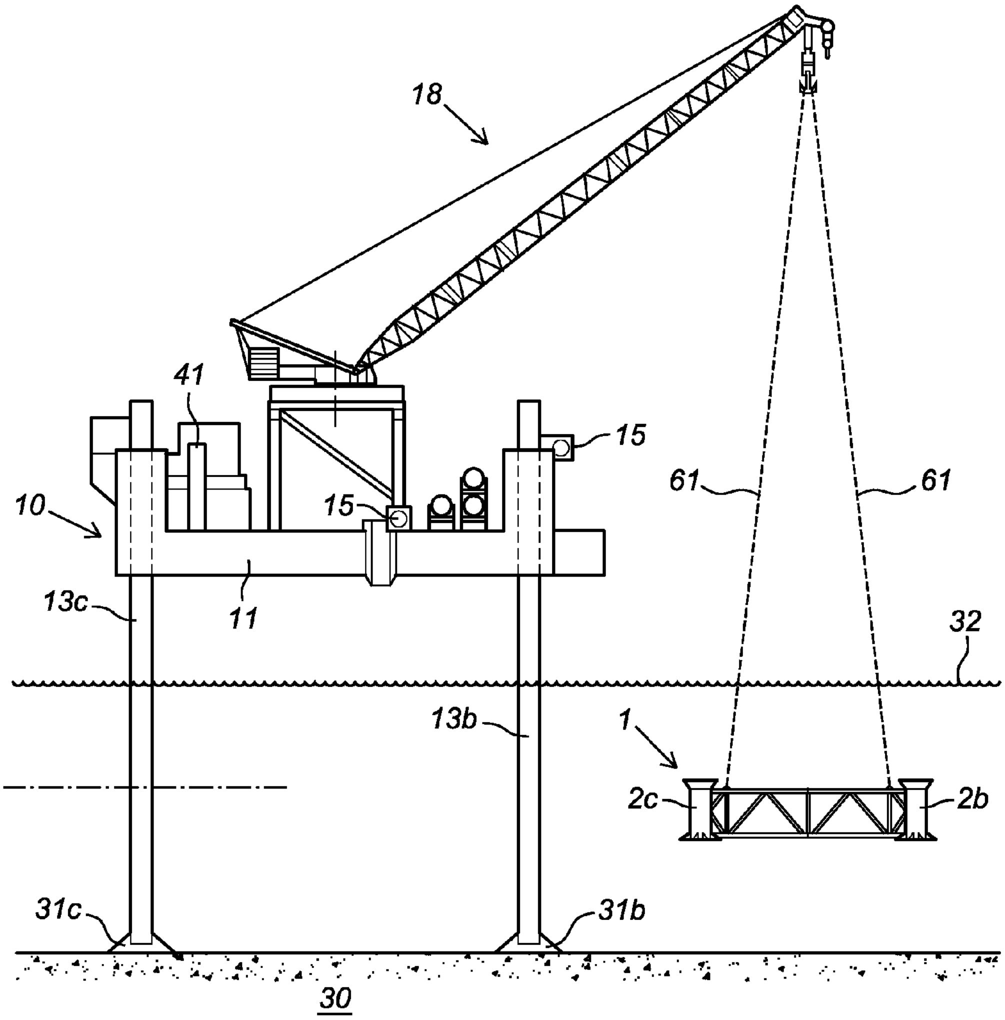


Fig. 3



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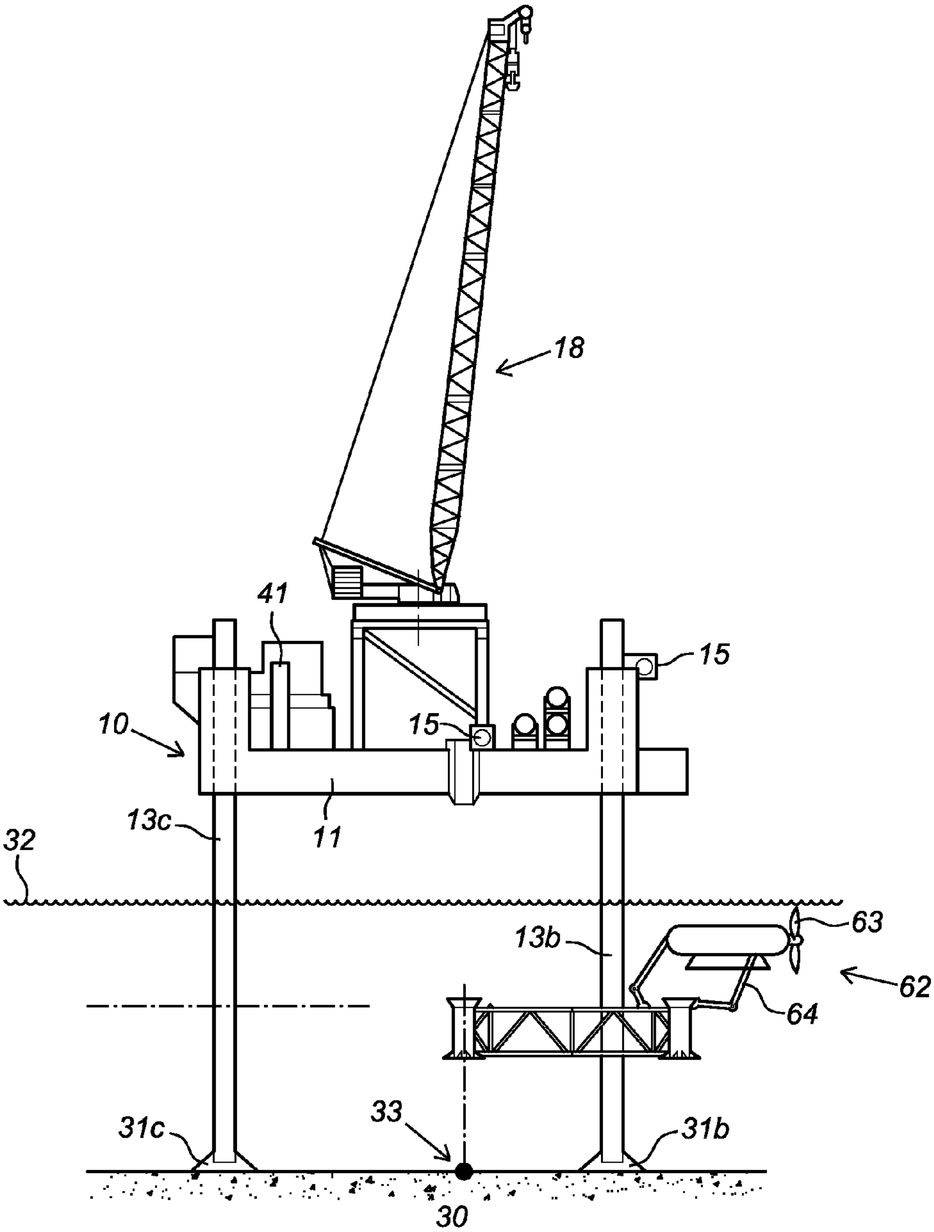
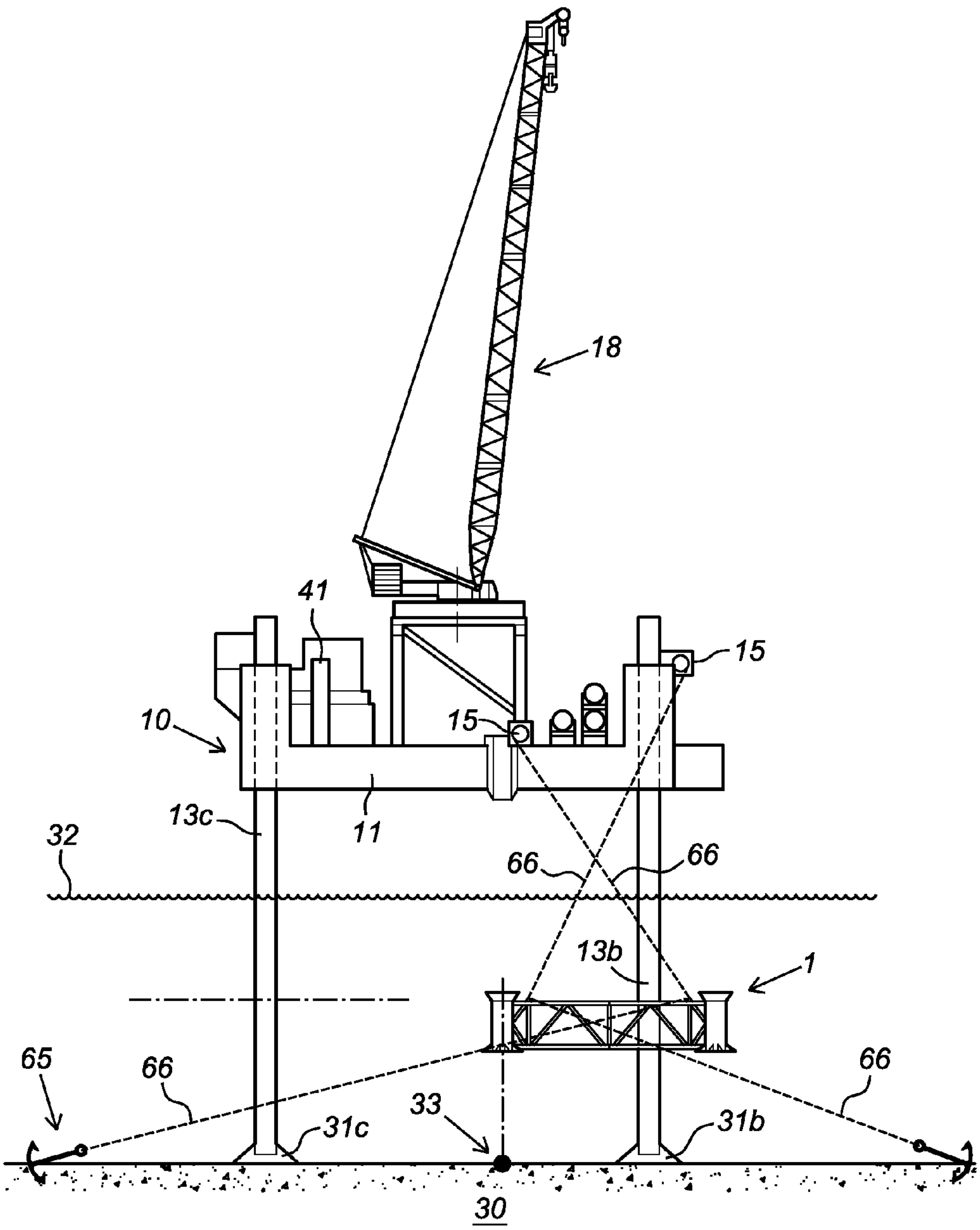


Fig. 5



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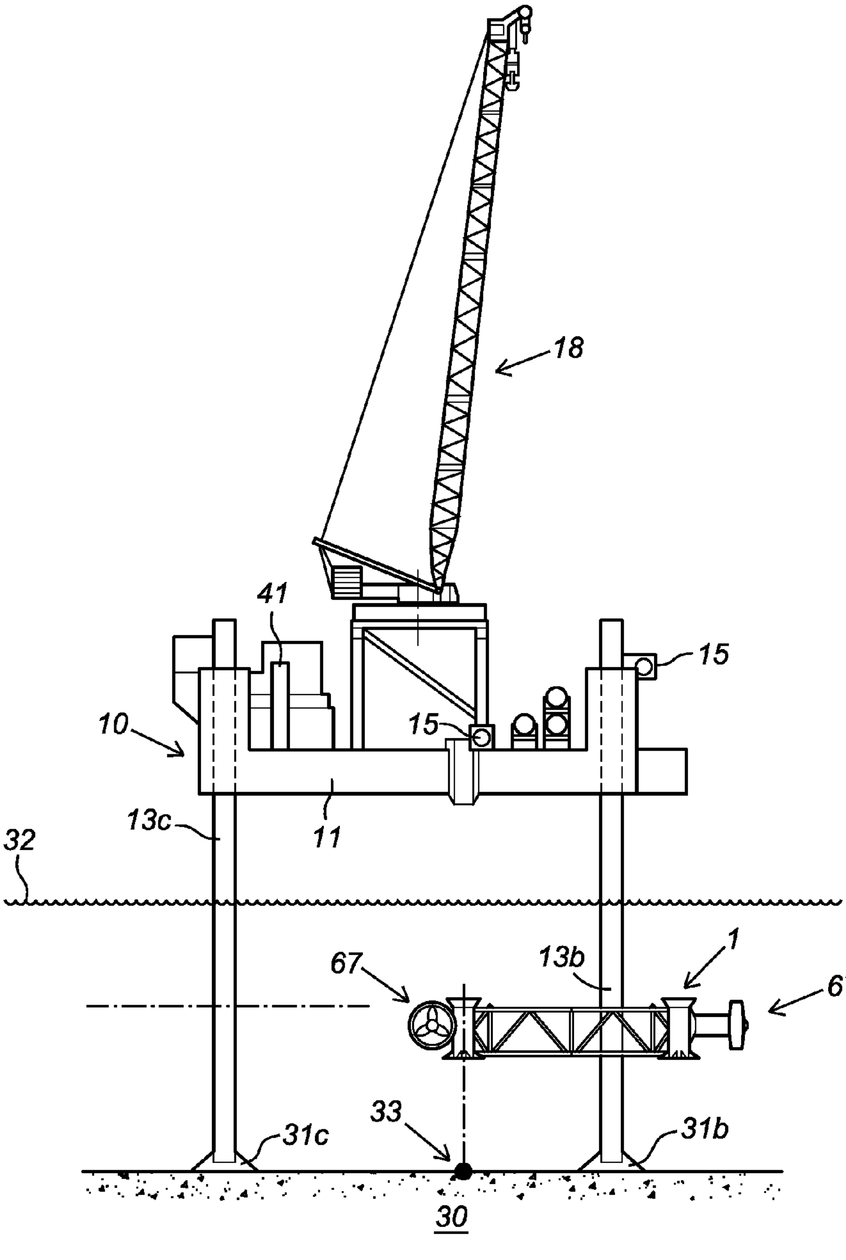

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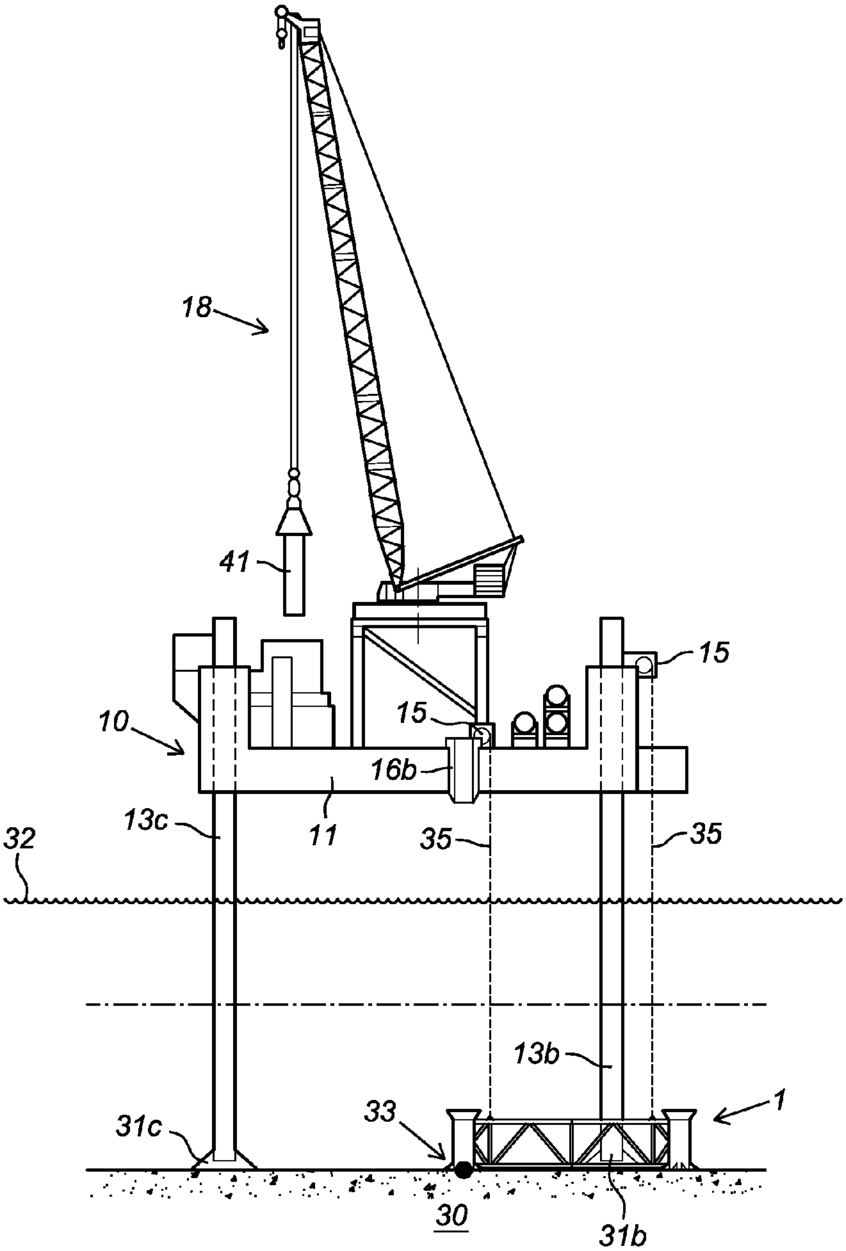

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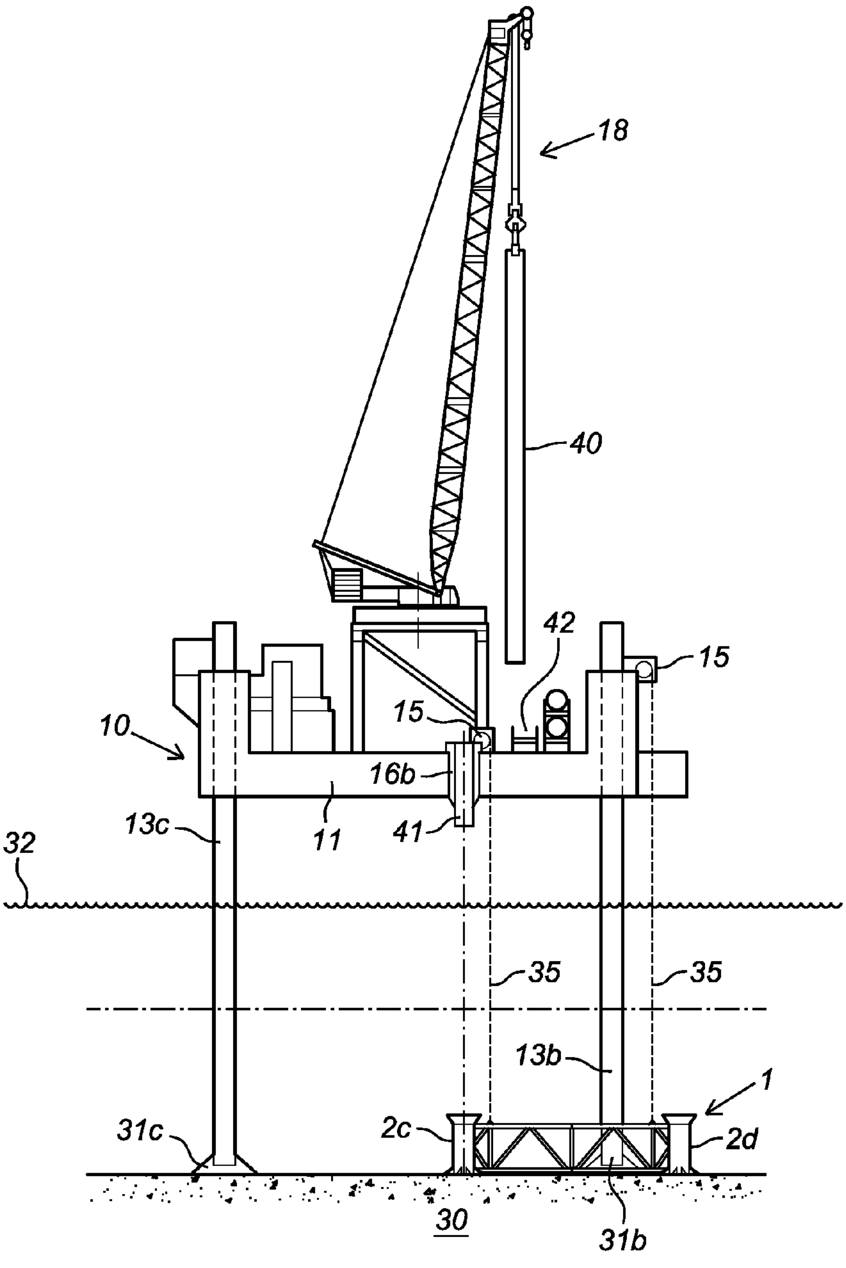

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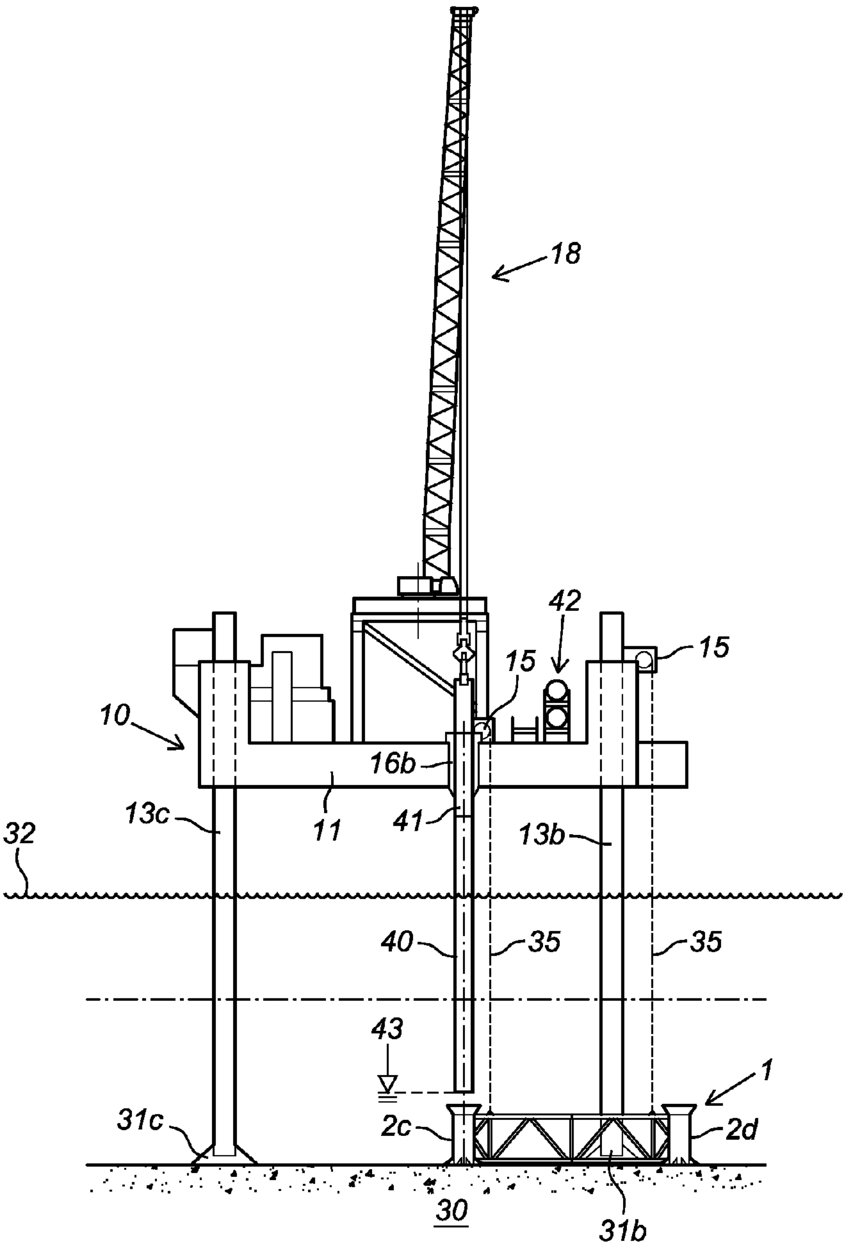

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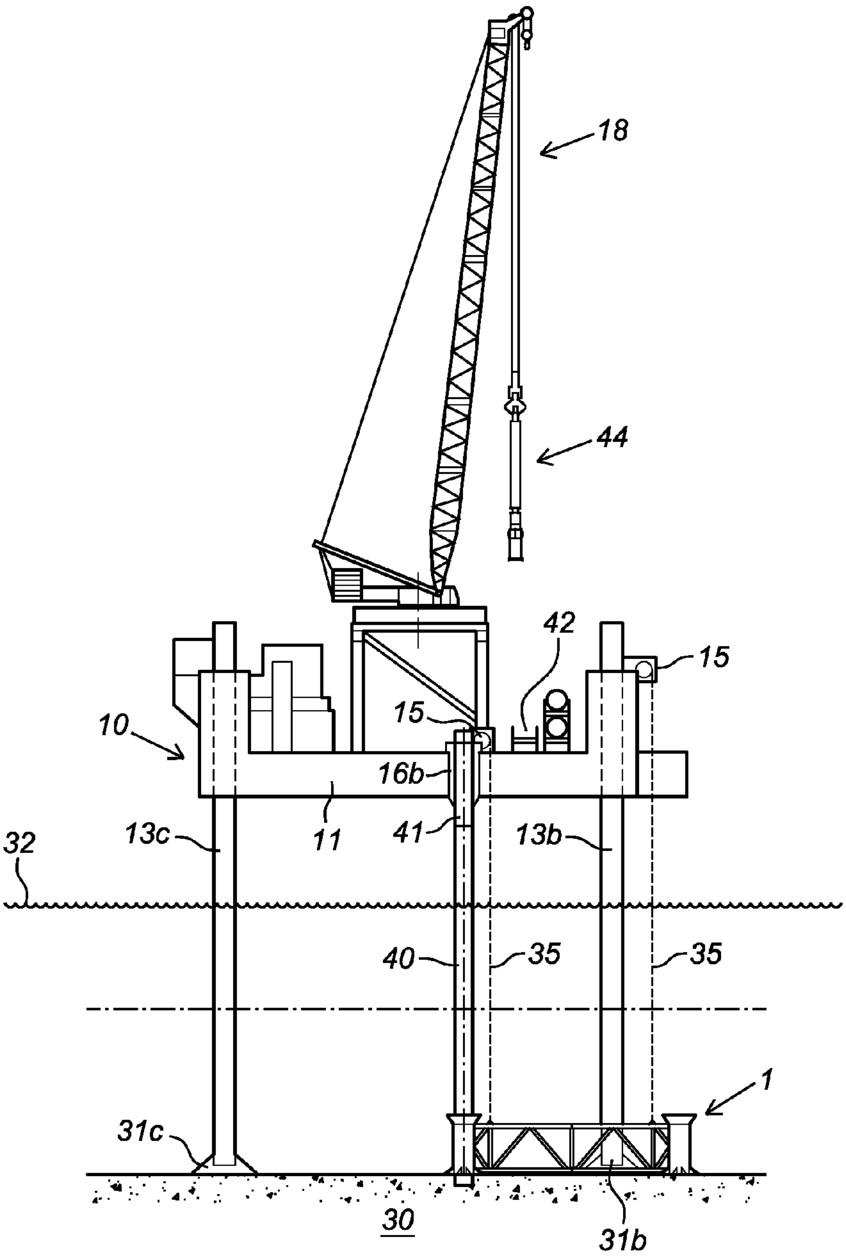

Fig. 11

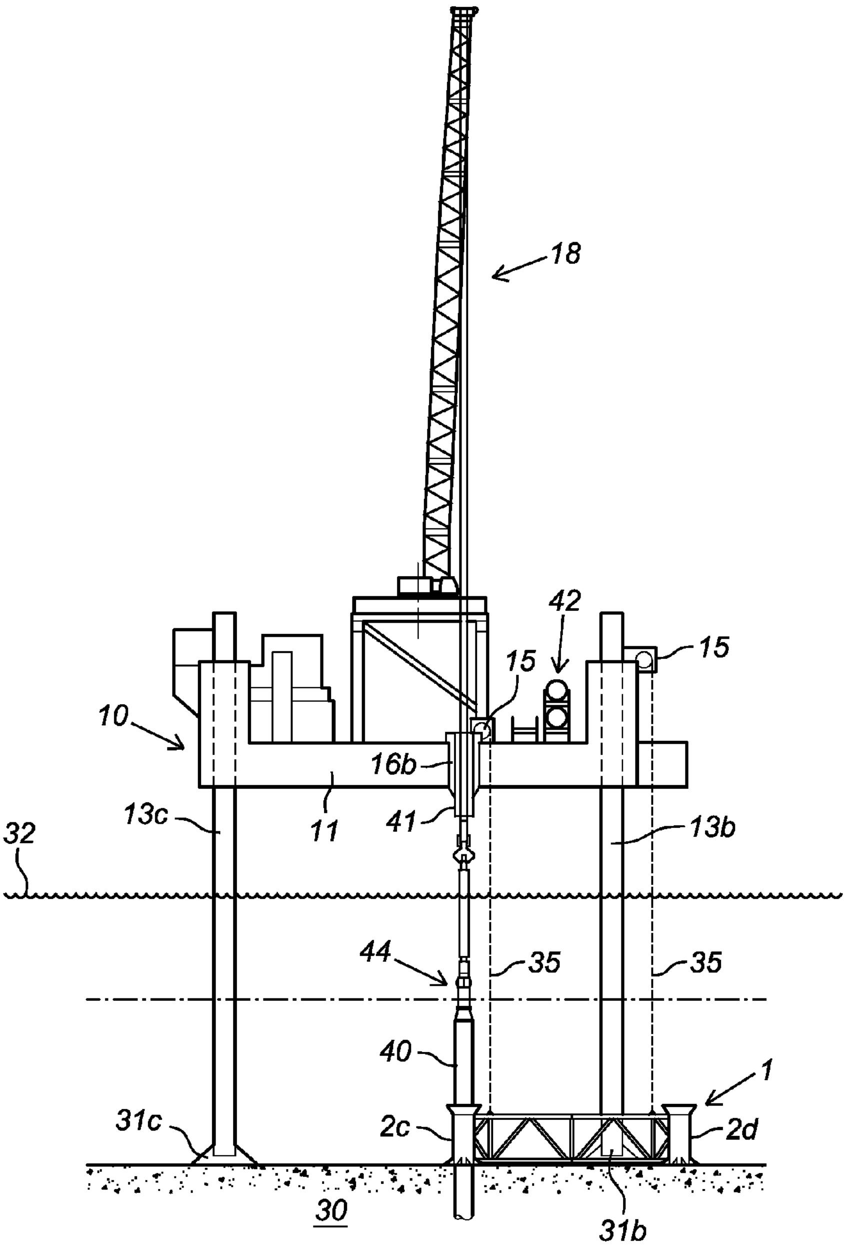

Fig. 12

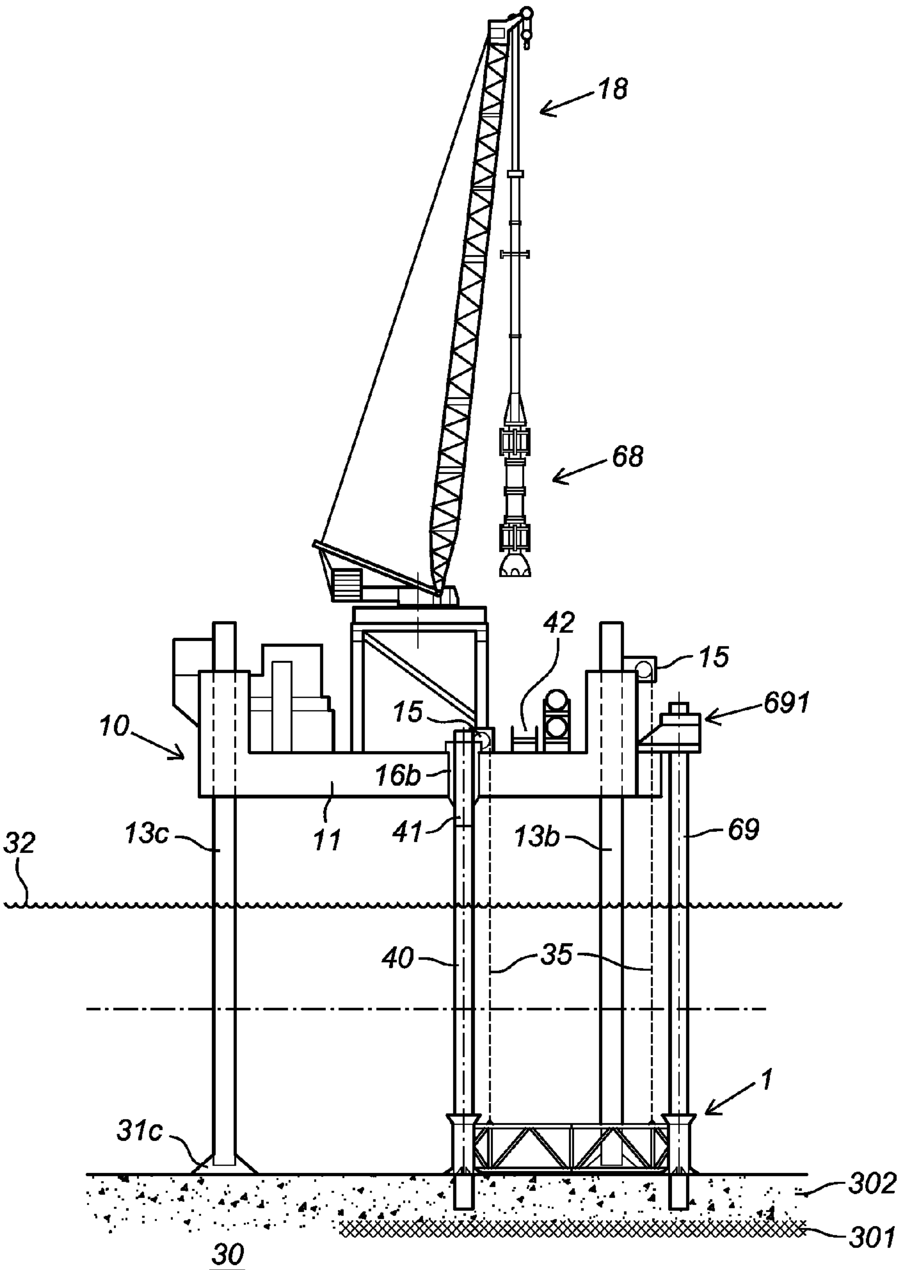

Fig. 13

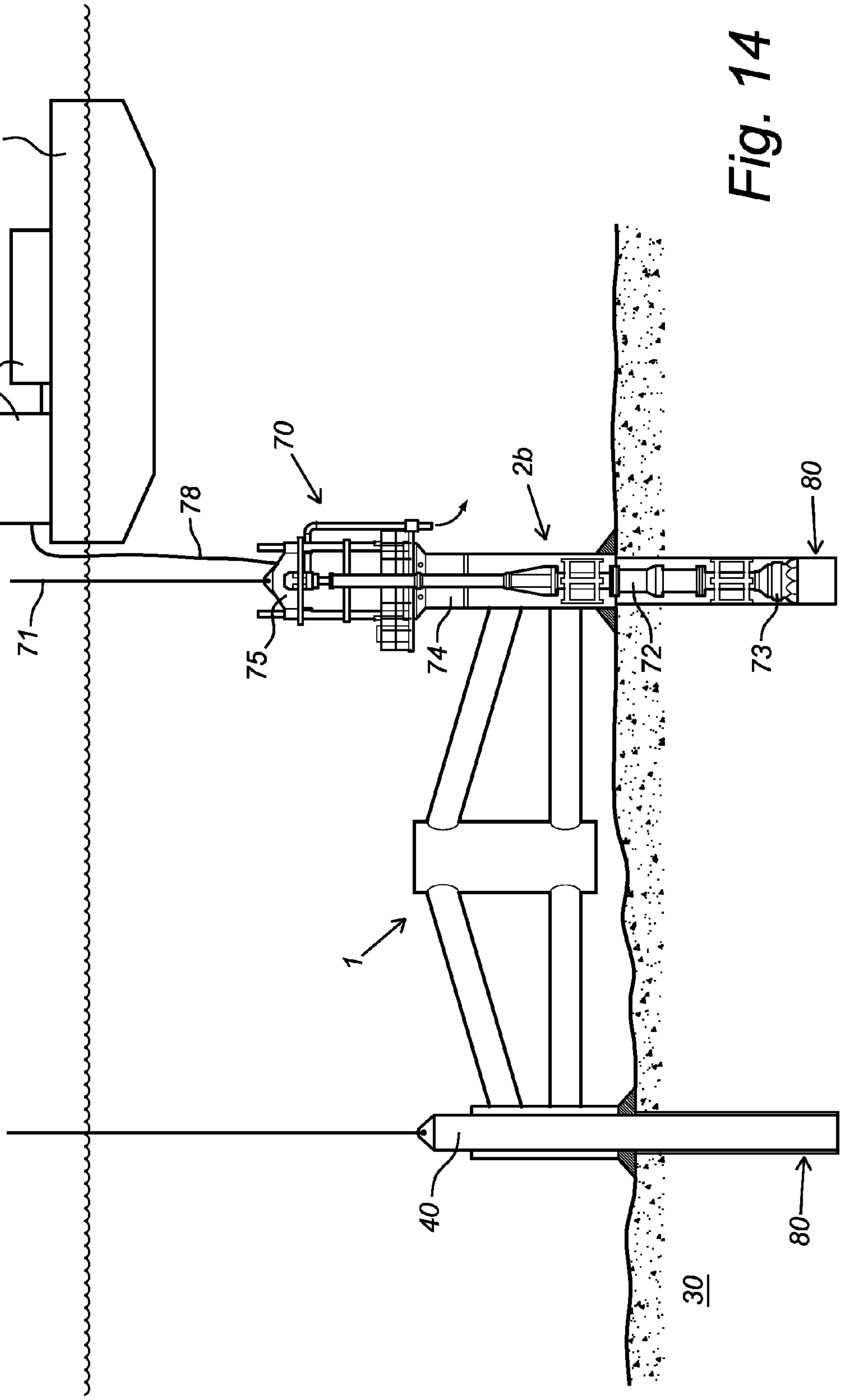

Fig. 14

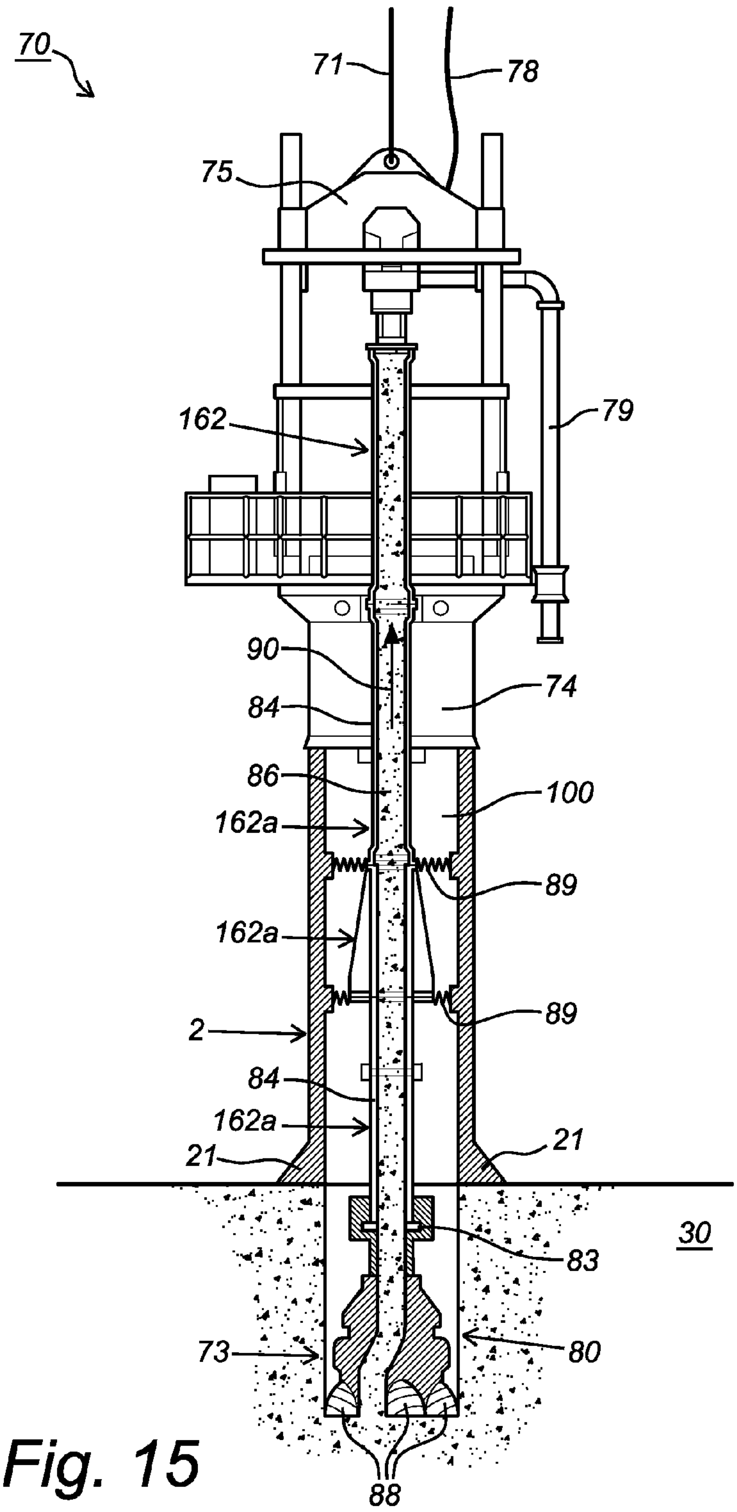
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Fig. 15

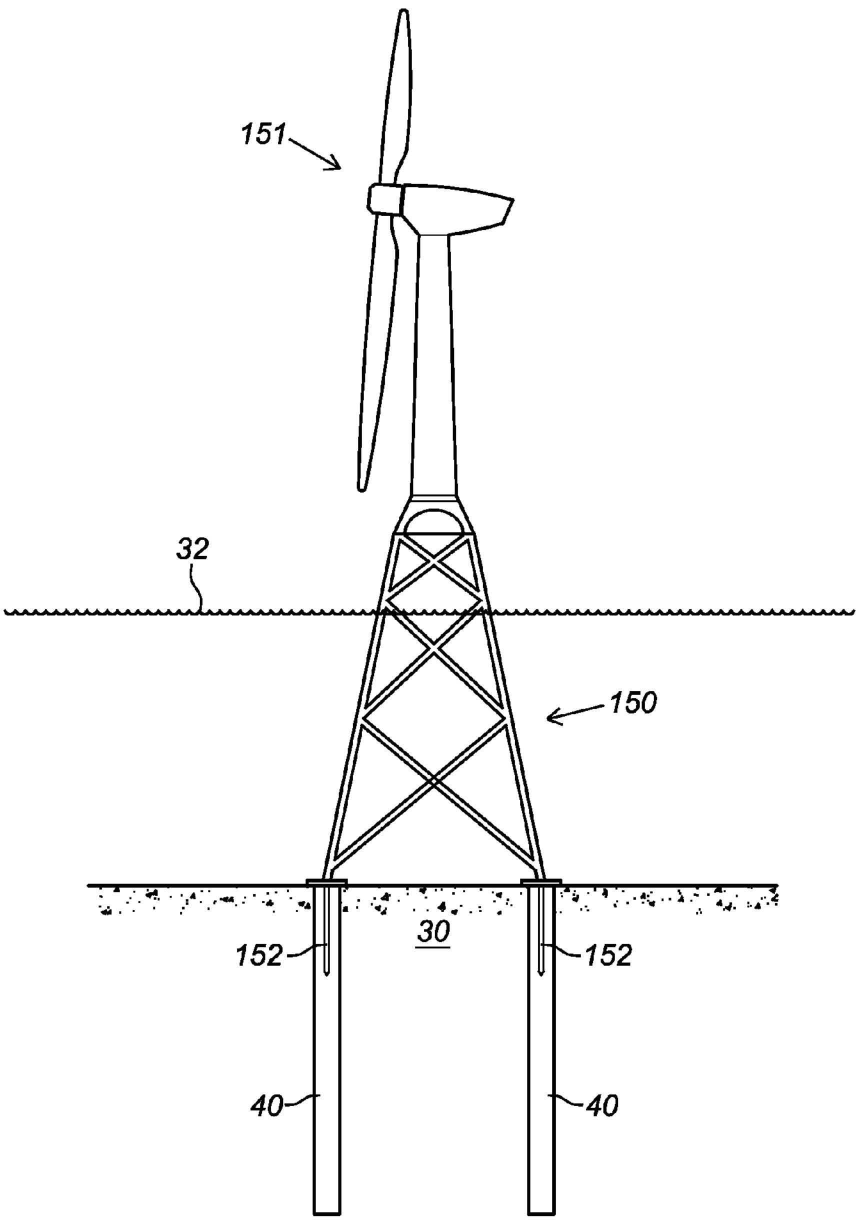

Fig. 16

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EUROPEAN SEARCH REPORT

Application Number
EP 12 17 5860

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E02D
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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	22 November 2012	Leroux, Corentine

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