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(54) **Subsea well intervention module**

(57) Subsea well intervention module for well intervention operations to be performed in a well from a surface vessel via a wireline. The intervention module comprises a supporting structure, an attachment means for removably attaching the supporting structure to a struc-

ture of a well head or an additional structure, a well manipulation assembly, a navigation means having at least one propulsion unit for manoeuvring the module in the water, and a control system for controlling the intervention operations.

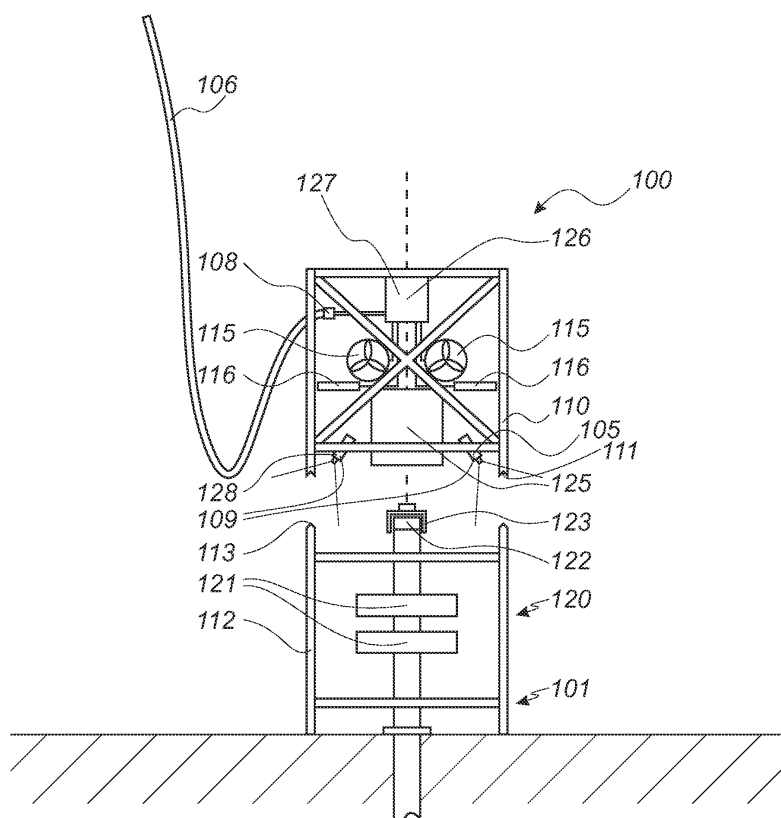


Fig. 2

Description

[0001] The present invention relates to a subsea well intervention module for well intervention operations to be performed in a well from a surface vessel via a wireline. The invention also relates to an intervention system and an intervention method.

Background

[0002] During production of oil, it may become necessary to perform maintenance work in a well, or to open a production well. Such well work is known as well intervention. Inside the well, a production casing is situated which in its upper end is closed by a well head. The well head can be situated on land, on an oil rig, or at the seabed below water.

[0003] When a well head is situated on the seabed on deep water, well intervention is more complicated since the visibility below water can be poor. Furthermore, the weather conditions at sea can interfere with the accomplishment of an intervention and, in case of a rough sea, interrupt the intervention.

[0004] In regard to such subsea intervention operations, it is known to perform these by lowering an intervention module down from a surface vessel onto the well head structure by means of a plurality of remotely operated vehicles (ROV). Firstly, the ROVs are submerged for securing a set of guide wires to the well head structure for a subsequent guidance and docking of the intervention module. These guide wires must be kept straight while the module is being lowered towards the well head where it is subsequently fastened by operational arms on the ROVs. The ROVs are subsequently used for performing the intervention operations.

[0005] For lowering such intervention modules onto a well head, a specially built vessel with a large crane is needed. Thus, each invention operation has to be thoroughly planned, since the special vessels are not available in every harbour and need to be transported to the nearest harbour, thus increasing both the time and money spent on each operation.

[0006] An intervention solution in which no guide wires are used is disclosed in US 7,331,394. Even though thrusters mounted on the module are used for assisting in manoeuvring the module onto the well head, the intervention module still needs to be lowered and hoisted by a crane on the surface vessel. Furthermore, ROVs are still needed for the docking procedure in order to both guide the module during lowering and to secure the module onto the well head, and for controlling the intervention operation.

Description of the Invention

[0007] An aspect of the present invention is, at least partly, to overcome the disadvantages of the above-mentioned known solutions to intervention operations subsea

by providing an improved subsea well intervention module that can be used with more commonly available surface vessels.

[0008] This aspect and the advantages becoming evident from the description below are obtained by a subsea well intervention module for well intervention operations to be performed in a well from a surface vessel via a wireline, comprising:

- a supporting structure,
- an attachment means for removably attaching the structure to a structure of a well head or an additional structure,
- a well manipulation assembly,
- a navigation means having at least one propulsion unit for manoeuvring the module in the water, and
- a control system for controlling the well manipulation assembly, the navigation means, and the intervention operations,

wherein the navigation means comprises a detection means for detection of a position of the intervention module.

[0009] By providing the intervention module with a detection means for detection of a position of the intervention module, an improved intervention module is obtained that eliminates the need for support from remotely operated vehicles (ROV), since the intervention module may be operated from the surface. Also, the navigation means enables the intervention module to manoeuvre independently in the water, further eliminating the need for external guidance or guide wires when docking on the well head.

[0010] In one embodiment, the supporting structure is a frame having an outer form and defining an internal space containing the well manipulation assembly, the navigation means, and the control system; the well manipulation assembly, the navigation means, and the control system all extending within the outer form.

[0011] In another embodiment, the detection means may use ultrasound, acoustic means, electromagnetic means, optics, or the like for detecting the position of the module and for navigating the module.

[0012] The navigation means may comprise a buoyancy system adapted for regulating a buoyancy of the submerged well intervention module.

[0013] In one embodiment, this buoyancy system comprises:

- a displacement tank,
- a control means for controlling the filling of the tank, and
- an expansion means for expelling sea water from the displacement tank when providing buoyancy to the module to compensate for a weight of the module itself in the water.

[0014] In another embodiment, the buoyancy system

comprises at least a first inflatable means and an expansion means for inflation of the inflatable means.

[0015] Naturally, elements of these two alternative embodiments of the buoyancy system may be combined in one buoyancy system.

[0016] In one embodiment of the invention, the subsea well intervention module has a longitudinal axis parallel to a longitudinal extension of the well, and the module is substantially weight symmetric around its longitudinal axis.

[0017] According to some embodiments, the module further comprises a power system for supplying power to an intervention operation which system comprises a power supplying means, such as such as a cable (106) from the surface vessel, a battery, a fuel cell, a diesel current generator, an alternator, a producer, or the like power supplying means.

[0018] In an embodiment of the invention, the power system positioned on the module provides power to at least the well manipulation assembly by means of hydraulic, pressurised gas, electricity, or the like energy sources.

[0019] Furthermore, in some embodiments, the power system comprises a power storage system for storage of energy generated from an intervention operation, such as submersion of an operational tool into the well.

[0020] Additionally, in some embodiments, the power system has at least one cable for supplying power from above surface to the module, the cable being detachably connected to the module.

[0021] In an embodiment, the cable further comprises means for transmitting signals between the module and the surface.

[0022] In some embodiments, the control system comprises disconnection means for disconnection of the cable for providing power to the system, the wireline for connection of the module to a vessel, or the attachment means.

[0023] In an advantageous embodiment, the detection means comprises at least one image recording means.

[0024] According to a particular embodiment of the invention, the well manipulation assembly of the subsea well intervention module comprises:

- a tool delivery system comprising:
 - at least one tool for submersion into the well, and
 - a tool submersion means for submerging the tool to the well through the well head,
- at least one well head connection means for connection to the well head, and
- a well head valve control means for operating at least a first well head valve for providing access of the tool into the well through the well head connection means.

[0025] In one embodiment, the tool submersion means

comprises an intervention means such as a winch uncoiling an intervention medium, such as a local wireline, braided line, or lightweight composite cable, connected to the tool for submerging the tool into the well and coiling the intervention medium when pulling the tool up from the well.

[0026] In a further embodiment, the tool delivery system comprises a plurality of tools in a tool exchanging assembly.

[0027] In an alternative embodiment, the well manipulation assembly comprises a cap removal means for removal of a protective cap on the well head.

[0028] According to some embodiments of the invention, the control system comprises disconnection means for disconnection of the well head connection means.

[0029] In an embodiment, the power system has an amount of reserve power enough for the control system to disconnect the well head connection means from the well head, the cable for providing power from the power system, the wireline from the module, or the attachment means from the well head structure.

[0030] Additionally, the invention also relates to a subsea well intervention system comprising

- at least one subsea intervention module according to any of the above-mentioned embodiments, and
- at least one remote control means for remotely controlling some or all functionalities of the module placeable above water.

[0031] In one embodiment, the well intervention system further comprises:

- at least one autonomous communication relay device for receiving signals from the intervention module, converting the signals into airborne signals, and transmitting the airborne signals to the remote control means, and vice versa to receive and convert signals from the remote control means and transmit the converted signals to the intervention module.

[0032] In a second embodiment of the subsea well intervention system, the autonomous communication relay device is designed as a buoy and has a resilient communication cable hanging underneath.

[0033] Finally, the invention relates to a subsea well intervention method comprising the steps of:

- positioning a surface vessel in vicinity of the subsea well head,
- connecting a subsea well intervention module to wireline on the vessel,
- dumping the subsea well intervention module into the sea from the surface vessel by pushing the module over an edge of the vessel,
- controlling the navigation means on the intervention module,

- manoeuvring the module onto the well head,
- connecting the module to the well head,
- controlling the control system to perform one or more intervention operations,
- detaching the module after the operations have been performed, and
- recovering the module onto the surface vessel by pulling in the wireline.

[0034] In one embodiment of the subsea well intervention method, one or more additional subsea well intervention modules are dumped sequentially after or simultaneously with the first module.

[0035] In a second embodiment of the subsea well intervention method, the subsea well intervention module from the onset of the intervention procedure is connected to the surface vessel by an umbilical, and the intervention further comprises the step of releasing the umbilical from the module while the module is submerged, after which the module may ascent in the water by its own navigation means without any physical connection to the surface vessel.

Brief Description of the Drawings

[0036] The invention is explained in detail below with reference to the drawings, in which

Fig. 1 is a schematic view of an intervention operation,

Fig. 2 is a schematic view of an intervention module according to the invention being docked on a well head,

Fig. 3 is a schematic view of an intervention module according to the invention,

Figs. 4 and 5 are schematic views of two embodiments of buoyancy systems according to the invention,

Fig. 6 is a schematic view of one embodiment of an intervention module,

Fig. 7 is a schematic view of another embodiment of an intervention module,

Fig. 8 shows one embodiment of a subsea well intervention system,

Fig. 9 shows another embodiment of the intervention system, and

Fig. 10 shows yet another embodiment of the intervention system.

[0037] The drawings are merely schematic and shown

for an illustrative purpose.

Detailed description of the invention

[0038] The present invention relates to a subsea well intervention module 100 for performing intervention operations on subsea oil wells 101 as shown in Fig. 1. The subsea intervention module 100 is launched from a surface vessel 102, e.g. by simply pushing the module 100 out into the sea from a deck in the back of the vessel or over a side 103 of the vessel 102. Due to the fact that launching of the intervention module can be made just by dumping the module into the water, launching is feasible by a greater variety of vessels, including vessels that are more commonly available. Thus, the intervention module 100 may also be launched into the water 104 by e.g. a crane (not shown).

[0039] After launch, the intervention module 100 navigates to the well 101 by means of a navigation means 105 to perform the intervention, as shown in Fig. 1. In another embodiment, the navigation means comprises communicational means that allows an operator, e.g. located on the surface vessel, to remotely control the intervention module via a control system 126. The remote control signals for the navigation means and the power to the intervention module are provided through a cable 106, such as an umbilical or a tether, which is spooled out from a cable winch 107.

[0040] A well head 120 located on the sea floor, shown in Fig. 2 and Fig. 7, is the upper termination of the well 101 and comprises two well head valves 121 and terminals for connection of a production pipe line (not shown) and for various permanent and temporary connections. The valves 121 may typically be operated mechanically, hydraulically, or both. At its top, the well head 120 has a protective cap 123 which must be removed before proceeding with the other intervention tasks. Typically, subsea well heads 120 are surrounded by carrying structures 112 to provide load relief for the well head itself when external units are connected. The carrying structure 112 may be equipped with two, three, or four attachment posts 113. The attachment means 113 of the intervention module 100 must be adapted to the specific type of carrying structure on the well head 120 that the intervention module is to be docked onto. The attachment means 111 may simply support the intervention module on the carrying structure by gravity, or it may comprise one or more locking devices to keep the module 100 in place on the well head 120 after docking has taken place.

[0041] Docking of the intervention module 100 is performed by a remote control, where the intervention module is navigated to the well head 120, rotated to be aligned with the well head structure, and steered to dock on the structure. To aid this docking procedure, the navigation means comprises a detection means for detection of the position of the intervention module in the water.

[0042] Having a intervention module 100 which is able to manoeuvre independently in the water 104 reduces

the requirements for the surface vessel 102, since the vessel 102 merely needs to launch the intervention module in the water after which the module is able to descend into the water under its own command, thus alleviating the need for expensive specially equipped surface vessels, e.g. with large heave-compensated crane systems (not shown).

[0043] The intervention module 100 may be remotely controlled by a combined power/control cable 106, by separate cables, or even wirelessly. Since the intervention module 100 comprises navigation means 105 enabling the module to move freely in the water, no guide wires or other external guiding mechanisms are needed to dock the module onto the well head 120. In some events, the wireline connection 108, 118 between the surface vessel and the module needs to be disconnected, and in these events the module of the present invention is still able to proceed with the operation. Furthermore, there is no need for launching additional vehicles, such as ROVs, to control the intervention module. This leads to a simpler operation, where the surface vessel 102 has a larger degree of flexibility e.g. to move away from approaching objects, etc.

[0044] The subsea well intervention module 100, 150, 160 according to the invention is formed by a supporting structure 110 onto which the various subsystems of the intervention module may be mounted. The supporting structure comprises attachment means 111 for removably attaching the supporting structure 110 to a structure 112 of a well head 120 or an additional structure of the well head. Thus, the attachment means 111 allows the intervention module to be docked on top of the well head. In another embodiment, the attachment means 111 of a second intervention module 160 can be docked on top of the first intervention module 150 already docked on the well head.

[0045] The first module is used for removing the cap of the well head and the second module is used for the intervention operation for launching a tool into the well.

[0046] When one intervention module operates in the well another intervention module is mounted with another tool for performing a second operation in the well also called a second run. When the module for second run is ready to use, the module is dumped into the water and waits in the vicinity of the well head ready to be mounted when the "first run" is finish. In this way, mounting of the tool for the next run can be performed while the previous run is performed.

[0047] As a result, each module can be mounted with one specific tool decreasing the weight of the module on the well head, since a module does not have a big tool delivery system with a lot of tools and means for handling the tools. Furthermore, the risk of a tool getting stuck in the tool delivery system does not exist. In addition, the may be more particularly designed for a certain purpose since other helping means can be build in relation to the tool which is not possible in a tool delivery system.

[0048] As shown in Fig. 2, the intervention module

comprises a well manipulation assembly 125 enabling the intervention module to perform various well intervention operations needed to complete an intervention job. Furthermore, the intervention module has a navigation means 105 having a propulsion unit 115, 116 for manoeuvring the module sideways in the water. However, the propulsion unit 115, 116 may also be designed to move the module up and down. Additionally, the intervention module has a control system 126 for controlling the well manipulation assembly, the navigation means 105, and the intervention operations, such as a tool 171 operating in the well.

[0049] The supporting structure 110 is made to allow water to pass through the structure, thus minimising the cross sectional area on which any water flow may act. Thus, the module can navigate faster through the water by reducing the drag of the module. Furthermore, an open structure enables easy access to the components of the intervention module.

[0050] In another embodiment, the supporting structure 110 is constructed at least partly as a tube frame structure since such a construction minimises weight. Thus, the supporting structure may be designed from hollow profiles, such as tubes for making the structure more lightweight. Such a lightweight intervention module results in reduced weight on the well head when the module is docked onto the same reducing the risk of damage to the well head. Furthermore, a lightweight intervention module enables an easier handling of the module 100, e.g. while aboard the surface vessel 102.

[0051] The supporting structure could be made in metals, such as steel or aluminium, or a light weight material weighing less than steel, such as a composite material, e.g. glass or carbon fibre reinforced polymers. Some parts of the supporting structure could also be made in polymeric materials

[0052] Other parts of the intervention module 100 could also be made in metals, such as steel or aluminium, or a light weight material weighing less than steel, such as polymers or a composite material, e.g. glass or carbon fibre reinforced polymers. Such other parts of the intervention module could be at least parts of the attachment means 111, the well manipulation assembly 125, the navigation means 105, the propulsion unit 115, 116, the control system 126, the detection means 109, the winch 127 un-coiling an intervention medium, e.g. a local wireline, the tool exchanging assembly, the tool delivery system 129, the power storage system 119 or the like means of the intervention module.

[0053] Fig. 3 shows how the supporting structure of an embodiment of the intervention module fully contains the navigation means, the control system and the well manipulation assembly within the outer form of the frame. Thus, the supporting structure protects the navigation means, the control system, and the well manipulation assembly from impact with e.g. the sea floor or objects on the surface vessel. Therefore, the intervention module is able to withstand being bumped against the sea floor

when it descends, and to lay directly on the sea floor e.g. when waiting to be docked on the well head.

[0054] In order to perform a well intervention, a cap of the well head has to be removed and subsequently, a tool is to be launched into the well as shown in Fig. 6.. Therefore, the first intervention module 150 to dock onto the well head is a module where the well manipulation assembly 125 comprises means for removing a protective cap. In a next intervention step, a second intervention 160 module comprising means for deploying a tool 171 into the well is docked onto the first intervention module 150. The first and the second module may, in another embodiment, be comprised in one module as shown in Figs. 2 and 7.

[0055] The detection means 109 uses ultrasound, acoustic means, electromagnetic means, optics, or a combination thereof for detecting the position of the module and for navigating the module onto the well head or another module. When using a combination of navigation techniques, the detection means can detect depth, position and orientation of the module. Ultrasound may be used to gauge the water depth beneath the intervention module and to determine the vertical position, and at the same time a gyroscope may be used to determine the orientation of the intervention module. One or more accelerometers may be used to determine movement in the horizontal plane with respect to a known initial position. Such a system may provide full position information of the intervention module.

[0056] In another embodiment, the detection means 109 comprises at least one image recording means, such as a video camera. Furthermore, the image recording means comprises means for relaying the image signals to the surface vessel via the control system. The video camera is preferably oriented to show the attachment means of the intervention module, as well as the well head during the docking procedure. This enables an operator to guide the intervention module by vision, e.g. while the module is being docked on the well head. As shown in Fig. 2, the image recording means may be mounted on the supporting structure of the intervention module in a fixed position, or be mounted on a directional mount that may be remotely controlled by an operator. Evidently to the person skilled in the art, the vision system may comprise any number of suitable light sources to illuminate objects within the optical path of the vision system.

[0057] In another embodiment, the image recording means further comprises means for analysing the recorded image signal, e.g. to enable an autonomous navigational system to manoeuvre the intervention module by vision.

[0058] To achieve a better manoeuvrability of the intervention module 100 while submerged, it must be able to maintain its vertical position within the water 104, simultaneously be able to move in the horizontal plane, and be able to rotate around a vertical axis 114, so that the attachment means may be aligned with the attach-

ment posts 113 of the carrying structure of the well head for docking.

[0059] Horizontal manoeuvrability as well as rotation may be provided by one or more propulsion units 115, 116, such as thrusters, water jets, or any other suitable means of underwater propulsion. In one embodiment, the propulsion units 115, 116 are mounted onto the intervention module in a fixed position, i.e. each propulsion unit 115, 116 has a fixed thrust direction in relation to the intervention module 100. In this embodiment, at three propulsion units is used to provide movability of the module. In another embodiment, the thrust direction from one or more of the propulsion units may be controlled, either by rotating the propulsion unit itself, or by directing the water flow, e.g. by use of a rudder arrangement or the like. Such a setup makes it possible to achieve full manoeuvrability with a fewer number of propulsion units than what is needed if the units are fixed to the intervention module.

[0060] A better vertical manoeuvrability may be achieved by providing the navigation means with a buoyancy system 117 adapted for regulating a buoyancy of the submerged well intervention module. By controlling the buoyancy of the intervention module 100 while submerged, the module may be made to sink (negative buoyancy), maintain a given depth (neutral buoyancy), or rise (positive buoyancy) in the water 104. By using this principle to provide a better vertical manoeuvrability, even heavy objects may be controlled efficiently, as exemplified by submarines that utilise such arrangements. In one embodiment, minor vertical position adjustments may be performed with a vertical propulsion unit 116 suitably oriented.

[0061] Providing the well intervention module 100 with substantially increased buoyancy has the additional effect that it lowers the resulting force exerted on the well head by the weight of the module. Preferably, the intervention module should be maintained at near neutral buoyancy, i.e. be "weightless". This lowers the risk of rupture of the well head, which would otherwise result in a massive environmental disaster.

[0062] The intervention module 100 may be remotely operated, be operated by an autonomous system, or any combination of the two. For example, in one embodiment, docking of the module is performed by a remote operator, but where an autonomous system maintains e.g. neutral buoyancy while the module is attached to the well head. The buoyancy system may furthermore provide means for adjusting the buoyancy to account for changes in density of the surrounding sea water, arising from e.g. changes in temperature or salinity.

[0063] Figs. 4 and 5 show two different embodiments of buoyancy systems 117, 117. Generally, the buoyancy system must be able to displace a mass of water corresponding to the total weight of the intervention module itself. For example, if the module weighs 30 tonnes, the mass of the water displaced must be 30 tonnes, roughly corresponding to a volume of 30 cubic metres, to estab-

lish neutral buoyancy. However, not the full volume will need to be filled with water for the module to descend, since this would make the module sink with a large velocity. Therefore, part of the buoyancy system 117 may be arranged to permanently provide buoyancy to the module, while part of the buoyancy system may displace a volume to adjust the buoyancy from negative to positive. The permanent buoyancy of the buoyancy system can be provided by a sealed off compartment of a displacement tank 130 that is filled with gas, or with a suitable low-density material, such as syntactic foam. The minimum buoyancy will depend on the drag of the module as it descends. Likewise, the maximum buoyancy obtainable should be selected to enable the module to ascent with a reasonably high speed to allow expedient operations, but not faster than safe navigation of the module mandates.

[0064] Fig. 4 shows a buoyancy system 117 comprising a displacement tank 130 that may be filled with seawater or with a gas, such as air. To increase the buoyancy of the module 100, gas is introduced into the tank 130, displacing seawater. To lower the buoyancy, gas is let out of the tank 130 by a control means 131, thus letting seawater in. The control means 131 for controlling the filling of the tank with seawater may simply be one or more remotely operated valves letting gas in the tank 130 escape. The tank may have an open bottom, or it may completely encapsulate the contents. In case of an open tank, water will automatically fill up the tank when the gas escapes, and in case of a closed tank, an inlet valve is needed to allow water to enter the tank 130.

[0065] Fig. 5 shows a buoyancy system 117 comprising a number of inflatable means 140 that may be inflated by expansion means 132. Any number of inflatable means 140 may be envisioned, e.g. one, two, three, four, five, or more. The inflatable means 140 may be formed as balloons, airtight bags, or the like, and may be inflated to increase buoyancy, e.g. when the intervention module is to ascend to the sea surface after the intervention procedure. The expansion means 132 may comprise compressed gas, such as air, helium, nitrogen, argon, etc. Alternatively, the gas needed for inflation of the inflatable means is generated by a chemical reaction, similar to the systems use for inflation of airbags in cars. The inflatable means must be fabricated from materials sufficiently strong to withstand the water pressure found at the desired operational depth. Such materials could be a polymer material reinforced with aramid or carbon fibres, with metal or with any other suitable reinforcement material. A buoyancy system 117 as shown in Fig. 5 may optionally comprise means for partly or fully releasing gas from an inflatable means 440, or even for releasing the whole inflatable means 140 itself.

[0066] In one embodiment, the intervention module 100, 150, 160 has a longitudinal axis parallel to a longitudinal extension of the well and the module is weight symmetric around its longitudinal axis. Such a symmetric weight distribution ensures that the intervention module

when docked onto the well head does not wrench the well head and the related well head structure.

[0067] In another embodiment, the buoyancy system 117 is adapted to ensure that the centre of buoyancy onto which the buoyant force acts is located on the same longitudinal axis as the centre of mass of the intervention module, and that the centre of buoyancy is located above the centre of mass. This embodiment ensures a directional stability of the intervention module.

[0068] As shown in Fig. 2, the intervention module 100, 150, 160 comprises a power system 119, which is positioned on the module. The power system can be in the form of a cable 106 connected to the surface vessel or in the form of a battery, a fuel cell, a diesel current generator, an alternator, a producer, or the like local power supplying means. In one embodiment, the power system powers the well manipulation assembly and/or other means of the module using hydraulic, pressurised gas, electricity, or the like energy. By providing a local power supplying means or a reserve power to the intervention module, the intervention module is able to release itself from the well head or another module and, if needed, bring up a tool in the well. This, at least, enables the intervention module to self-surface, should such damage or other emergencies occur. In another embodiment, the local power supplying means allows the intervention module to independently perform parts of the intervention procedure without an external power supply.

[0069] In some embodiments, the power system 119 comprises a power storage system 133 for storage of energy generated from intervention operations, such as submersion of an operational tool into the well. In one such embodiment, the power storage system 133 comprises a mechanical storage of the energy released as the tool 171 is lowered within the well, which stored energy can be used for a later hoisting of the tool. The power storage system may comprise a mechanical storage means being any kind of a tension system, pneumatic storage means, hydraulic storage means, or any other suitable mechanical storage means. By providing the intervention module with a power storage system 119, the required capacity of e.g. electrical power needed for operations are lowered, due to the reuse of stored energy. Of course the intervention module may comprise any combination of two or more power supplying means.

[0070] Furthermore, the power system of the intervention module may be powered by at least one cable 106 for supplying power from above surface to the intervention module. The cable is detachably connected to the intervention module in a connection 108 enabling an easy separation of the cable from the intervention module in the event that the surface vessel needs to move. This is shown in Fig. 6, where the cable has just been detached. The cable may be adapted to supply the intervention module with electrical power from the surface vessel, and may e.g. be provided as an umbilical or a tether.

[0071] Communication with the surface vessel enables the intervention module to be remotely operated,

and to transmit various measurement and status data back to the vessel. The intervention module may communicate by wire or wirelessly with the surface vessel or with other units, submerged or on the surface. The communication wire may be a dedicated communication line provided as a separate cable or as a separate line within a power cable, or a power delivery wire connection, such as a power cable. In another embodiment, as shown in Figs. 8 and 9, the intervention module comprises wireless communicational means, which could be radio frequency communication, acoustic data transmission, an optical link, or any other suitable means of wireless underwater communication. Communication may take place directly with the intended recipient, or by proxy, i.e. intermediate sender and receiver units, such as relay devices 190. The communication means may enable bi- or unidirectional communication communicating such data from the intervention module as a video feed during the docking procedure, position, current depth reading, status of subsystems, or other measurement data, e.g. from within the well. Communication to the intervention module could be requests for return data, manoeuvring operations, control data for the well manipulation assembly, i.e. controlling the actual intervention process itself, etc.

[0072] In one embodiment, the control system comprises both wired and wireless communicational means, e.g. such that a high-bandwidth demanding video feed may be transmitted by wire until the intervention module has been docked on the well head. After the module has been docked, less bandwidth-demanding communications, such as communication needed during the intervention itself, may be performed wirelessly by means of relay devices 190.

[0073] If the communication wire, e.g. combined with a power cable, is released from the intervention module, no physical connection is required between any surface or submerged vessel and the intervention module, due to the fact that the intervention module may still be controlled by the wireless connection 180, 191. Thus, in one embodiment, the control system comprises disconnection means 108, for disconnection of the cable for providing power to the system, a wireline for connection of the intervention module to a vessel, or the attachment means. Subsequent to the disconnection, the intervention module continues to function from its own power supply. When the cable has been released from the intervention module and recovered on the surface vessel, the vessel is free to navigate out of position, e.g. to avoid danger from floating obstacles, such as icebergs, ships, etc.

[0074] As mentioned, in order to perform the actual intervention tasks, the module comprises a well manipulation assembly 125 which may be a cap removal means 134 or tool delivery system 129. The tool delivery system 129 comprises at least one tool 171 for submersion into the well, and a tool submersion means for submerging the tool into the well through the well head. Having a tool submersion means of the tool delivery system mounted

on the module makes handling of the tool independent from the surface vessel. This ensures that the well head is not subject to any undue strain or torque from e.g. a long wire line or guide wires extending from the well head to the surface vessel. Such strain or torque is highly unwanted, since this may ultimately lead to rupture of the well head, which could potentially lead to a massive environmental disaster. To connect the well manipulation assembly 125 to the well head, the assembly further comprises at least one well head connection means 173, and a well head valve control means 174 for operating at least a first well head valve for providing access of the tool into the well through the well head connection means 173. Well heads typically have either mechanically or hydraulically operated valves. Thus, the well head valve control means 174, controlled by the intervention modules control system, comprises means for operating the valve controls, such as a mechanical arm or a hydraulic connection, and a system for delivering the required mechanical or hydraulic force to the valve controls.

[0075] The tool submersion means may be a winch uncoiling an intervention medium, such as a local wireline, braided line, or lightweight composite cable, connected to the tool for submerging the tool into the well and coiling the intervention medium when pulling the tool up from the well.

[0076] Well interventions commonly require tools to be submerged into the well by wireline, coiled tubing, etc. In the event that part of the well is not substantially vertical, a downhole tractor can be used to drive the tool all the way into position in the well. A downhole tractor is any kind of driving tool capable of pushing or pulling tools in a well downhole, such as a Well Tractor®.

[0077] The connection means typically comprises a lubricator 178 for connecting to the well head and for taking up the tool when it is not deployed. Furthermore, the connection means typically comprises a grease injection head for establishing a tight seal around the tool submersion means, while still allowing the tool submersion means to pass through the sealing for moving the tool in and out of the well. In one embodiment, the control system comprises disconnection means for disconnection of the well head connection means 173 enabling the lubricator to be disconnected from the well head. In case of an emergency, the tool comprises a release device for releasing the cable from the tool in the event that the tool gets stuck downhole.

[0078] In a further embodiment, the power system 119 has an amount of reserve power large enough for the control system to disconnect the well head connection means from the well head, the cable for providing power from the power system, the wireline from the module, and/or the attachment means from the well head structure. Hereby, the intervention module can resurface even if a cable needs to be disconnected, e.g. due to an oncoming risk to the surface vessel. In one embodiment, the required reserve power may be provided by equipping the intervention module with a suitable number of

batteries enabling the required operations.

[0079] The well intervention module 100, 150 may also comprise two or more tools that are stored in a tool exchanging assembly while the tools are not deployed. The tool exchanging assembly, controlled by the control system, enables tool exchange between the two or more tools so that multiple intervention operations requiring different tools may be performed by the same module without the need for the module to resurface, or other outside influence.

[0080] A typical intervention operation will require at least one additional configuration of the well manipulation assembly 125, besides the configuration with a tool. As mentioned, the additional configuration can be a cap removal assembly 151 comprising cap removal means 134, as shown in Fig. 6. Such cap removal means 134 may be adapted to pull or unscrew the protective cap 123 of the well, depending on the design of the well head 120 and/or the protective cap 123. Furthermore, the cap removal means 134 may be adapted to vibrate the cap 123 to loosen debris and sediments that may have been deposited on the cap.

[0081] As mentioned, the cap removal assembly 151 may be mounted on a special intervention module dedicated to being a cap removal module 150. This cap removal module 150 may be adapted to allow subsequent intervention modules 100, 160 to be docked in extension to itself, when attached to the well head 120. The module shown in Fig. 6 comprises receiving means 155 towards the top of the supporting structure, where the receiving means 155 are adapted to receive the attachment means 111 of a subsequent intervention module 100, 160. In the embodiment shown in the figure, the cable has now been detached from the module so as to be recovered by the surface vessel. The control system of the cap removal module is now communicationally connected to the surface vessel by a wireless link.

[0082] As shown in Fig. 9, some embodiments of the intervention system comprise at least one autonomous communication relay device 191 for wirelessly receiving waterborne signals 180 from the intervention module 100, 150, 160, converting the signals from the module into airborne signals 191, and transmitting the airborne signals to the remote control means 192, and vice versa to receive and convert signals from the remote control means and transmit the converted signals to the intervention module.

[0083] In an embodiment, the autonomous communication relay device 190 is designed as a buoy and has a resilient communication cable 194, 199 hanging underneath. The communication relay device may be a small vessel, a dinghy, a buoy, or any other suitable floating structure. Preferably, the relay device 190 comprises navigation means so that it may be remotely controlled from the surface vessel, e.g. to maintain a specific position. Also, in some embodiments, the relay device comprises means for detecting its current position, such as a receiver 193 for the Global Positioning System (GPS).

In Fig. 8, the resilient communication cable hangs underneath the vessel where the end of the cable has means for communicating with a first 100, 150 and a second 100, 160 module.

[0084] Airborne communication to and from the intervention module is relayed between underwater communicational means and above-surface communicational means, such as antennas 192, as seen in Fig. 9. Underwater communication means may be a wire that is connected to the intervention module (see Fig. 10), or it may be means for wireless underwater communication, e.g. by use of radio frequency signals or optical or acoustic signals. If wireless communication is used, the communicational relay device may be adapted for lowering the underwater communicational means far down into the water, e.g. to reach depths of 10-100%, alternatively 25-75%, or even 40-60% of the water depth. This limits the required underwater wireless transmission distance, as it may be required to circumvent the excessively large transmission losses of electromagnetic radiation in sea water. Airborne communication may take place with the surface vessel, or with e.g. a remote operations centre.

[0085] Fig. 10 shows an embodiment where the underwater communication means of the relay device is a communication wire 199 that is connected to the intervention module 100, and that may be pulled out from the relay device 190 as the intervention module descends. The relay device may be provided with means for spooling out the wire, or the wire may simply be pulled from a spool by the weight of the intervention module as the module descends. The wire may be hoisted either by electro-mechanical means, such as a winch, or by purely mechanical means, such as a tension system.

[0086] A subsea well intervention utilising intervention modules according to the present intervention thus comprises the steps of:

- positioning a surface vessel in vicinity of the subsea well head,
- connecting a subsea well intervention module to a wireline on the vessel,
- dumping the subsea well intervention module into the sea from the surface vessel by pushing the module over an edge of the vessel,
- controlling the navigation means on the intervention module,
- manoeuvring the module onto the well head,
- connecting the module onto the well head,
- controlling the control system to perform one or more intervention operations,
- detaching the module from the well head after the operations have been performed, and
- recovering the module onto the surface vessel by pulling in the wireline. The surface vessel does not need to be accurately positioned over the well head, since the module navigates independently and is not suspended from the vessel. Furthermore, the often critical prior art procedure of deploying the interven-

tion module into the water is significantly simplified since the module may merely be pushed over the side of the surface vessel. This enables deployment of an intervention module in rough conditions which would otherwise be prohibitive for intervention operations. Also, since the module is remotely operated, there is no need for deploying additional vehicles, such as ROVs, thus further simplifying the intervention operation.

[0087] In some embodiments of the intervention method according to the invention, one or more additional sub-sea well intervention modules are dumped sequentially after or simultaneously with the first module. As the first intervention module performs its designated operations, the next intervention module may be prepared on the surface vessel, and launched into the sea to descend towards the well head. When the first intervention module has fulfilled its operations, it may return to the surface by its own means, while the second intervention module waits in the proximity of the well head to be docked on the well head. By having an awaiting second intervention module, a quick change from one intervention module to the next is possible, when compared to the situation where multiple intervention modules need to be lowered by crane onto the well head, e.g. via a set of guide wires. In that case, more time is needed to perform the intervention.

Claims

1. Subsea well intervention module (100) for well intervention operations to be performed in a well (101) from a surface vessel (102) via a wireline, comprising:

- a supporting structure (110),
- an attachment means (111) for removably attaching the supporting structure to a structure of a well head (120) or an additional structure,
- a well manipulation assembly (125),
- a navigation means (105) having at least one propulsion unit (115, 116) for manoeuvring the module in the water (104), and
- a control system (126) for controlling the well manipulation assembly (125), the navigation means, and the intervention operations,

wherein the navigation means (109, 117) comprises a detection means (109) for detection of a position of the intervention module.

2. Subsea well intervention module according to claim 1, wherein the supporting structure is a frame having an outer form and defining an internal space containing the well manipulation assembly, the navigation means, and the control system; the well manip-

ulation assembly, the navigation means, and the control system all extending within the outer form.

3. Subsea well intervention module according to claim 1 or 2, wherein the navigation means comprises a buoyancy system (117) adapted for regulating a buoyancy of the submerged well intervention module.
4. Subsea well intervention module according to claim 3, wherein the buoyancy system comprises:
 - a displacement tank (130),
 - a control means (131) for controlling the filling of the tank, and
 - an expansion means (132) for expelling sea water from the displacement tank when providing buoyancy to the module to compensate for the weight of the intervention module itself in the water.
5. Subsea well intervention module according to any one of the preceding claims, wherein the detection means comprises at least one image recording means.
6. Subsea well intervention module according to any one of the preceding claims, wherein the well manipulation assembly comprises:
 - a tool delivery system (170) comprising:
 - at least one tool (171) for submersion into the well, and
 - a tool submersion means (172) for submerging the tool into the well through the well head,
 - at least one well head connection means (173) for connection to the well head, and
 - a well head valve control means (174) for operating at least a first well head valve (121) for providing access of the tool into the well through the well head connection means.
7. Subsea well intervention module according to any one of the preceding claims, wherein the well manipulation assembly comprises a cap removal means (134) for removal of a protective cap (123) on the well head.
8. Subsea well intervention module according to any one of the preceding claims, further comprising a power system (119) for supplying power to an intervention operation, such as a cable (106) from the surface vessel, a battery, a fuel cell, a diesel current generator, an alternator, a producer, or the like power supplying means.
9. Subsea well intervention module according to claim 8, wherein the power system-comprises a power

storage system (133) for storage of energy generated from an intervention operation, such as submersion of an operational tool (171) into the well.

10. Subsea well intervention module according to claim 8 or 9, wherein the power system has an amount of reserve power large enough for the control system to disconnect the well head connection means from the well head, the cable for providing power from the power system, the wireline from the intervention module, or the attachment means from the well head structure. 5 10
11. Subsea well intervention system (200) comprising 15
 - at least one subsea intervention module according to any one of claims 1-10, and
 - at least one remote control means (191, 192) for remotely controlling some or all functionalities of the intervention module, the remote control means being positioned above water. 20
12. Subsea well intervention system according to claim 11, further comprising 25
 - at least one autonomous communication relay device (190) for receiving signals from the intervention module, converting the signals into airborne signals, and transmitting the airborne signals to the remote control means, and vice versa to receive and convert signals from the remote control means and transmit the converted signals to the intervention module. 30
13. Subsea well intervention system according to any of the preceding claims, wherein the intervention module or parts of the intervention module is made in metals, such as steel or aluminium, or a light weight material weighing less than steel, such as polymers or a composite material, e.g. glass or carbon fibre reinforced polymers. 35 40
14. Subsea well intervention system according to claim 13, wherein the parts of the intervention module are least parts of the attachment means, the well manipulation assembly, the navigation means, the propulsion unit, the control system, the detection means, the winch un-coiling an intervention medium e.g. a local wireline, the tool exchanging assembly, the tool delivery system, the power storage system or the like means of the intervention module. 45 50
15. Subsea well intervention method comprising the steps of: 55
 - positioning a surface vessel in vicinity of the subsea well head,
 - connecting a subsea well intervention module

to the wireline on the vessel,

- dumping the subsea well intervention module into the water from the surface vessel by pushing the module over an side or end of the vessel,
- controlling the navigation means on the intervention module,
- manoeuvring the module onto the well head,
- connecting the module to the well head,
- controlling the control system to perform one or more intervention operations,
- detaching the module from the well head after the operations have been performed, and
- recovering the module onto the surface vessel by pulling in the wireline.

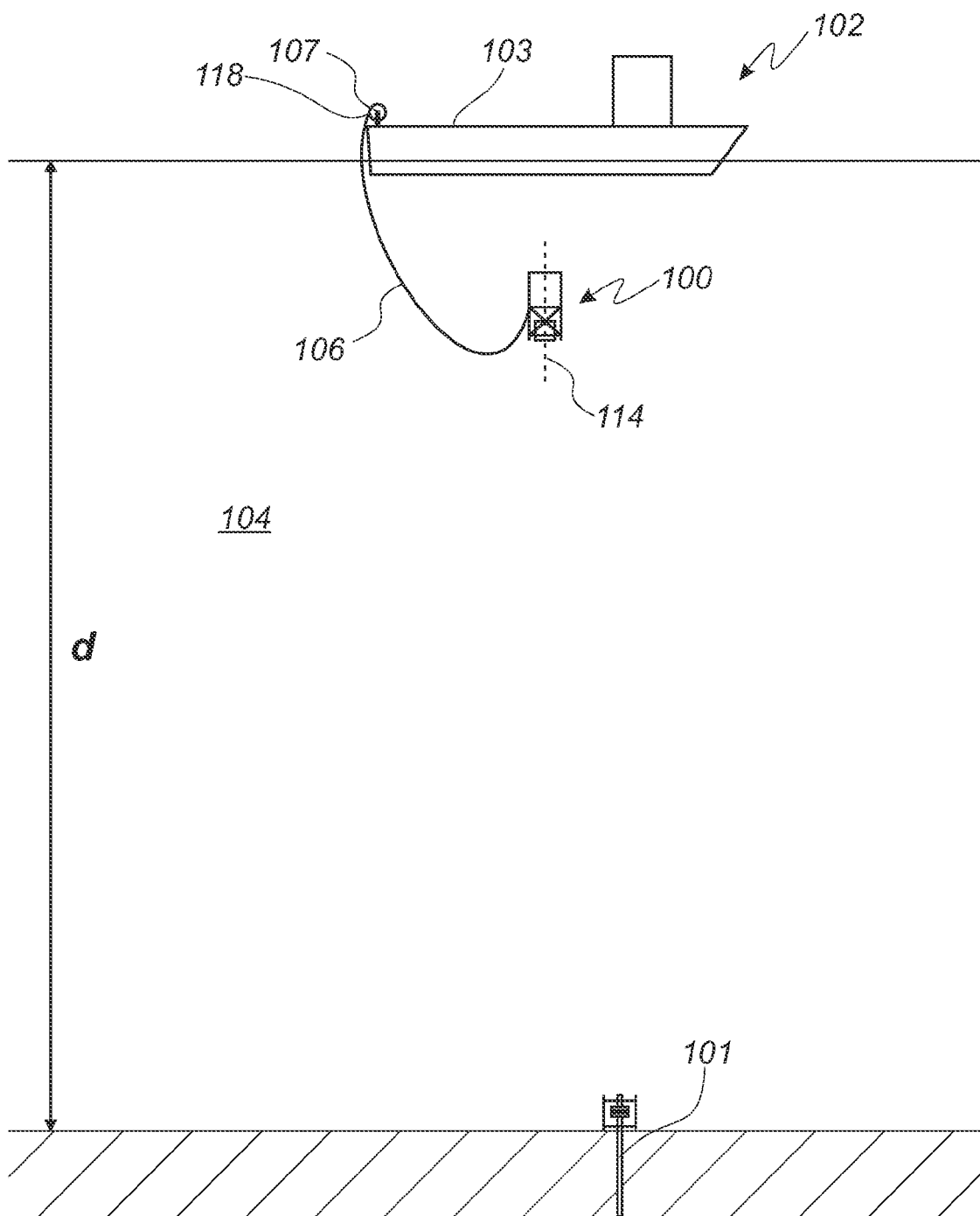


Fig. 1

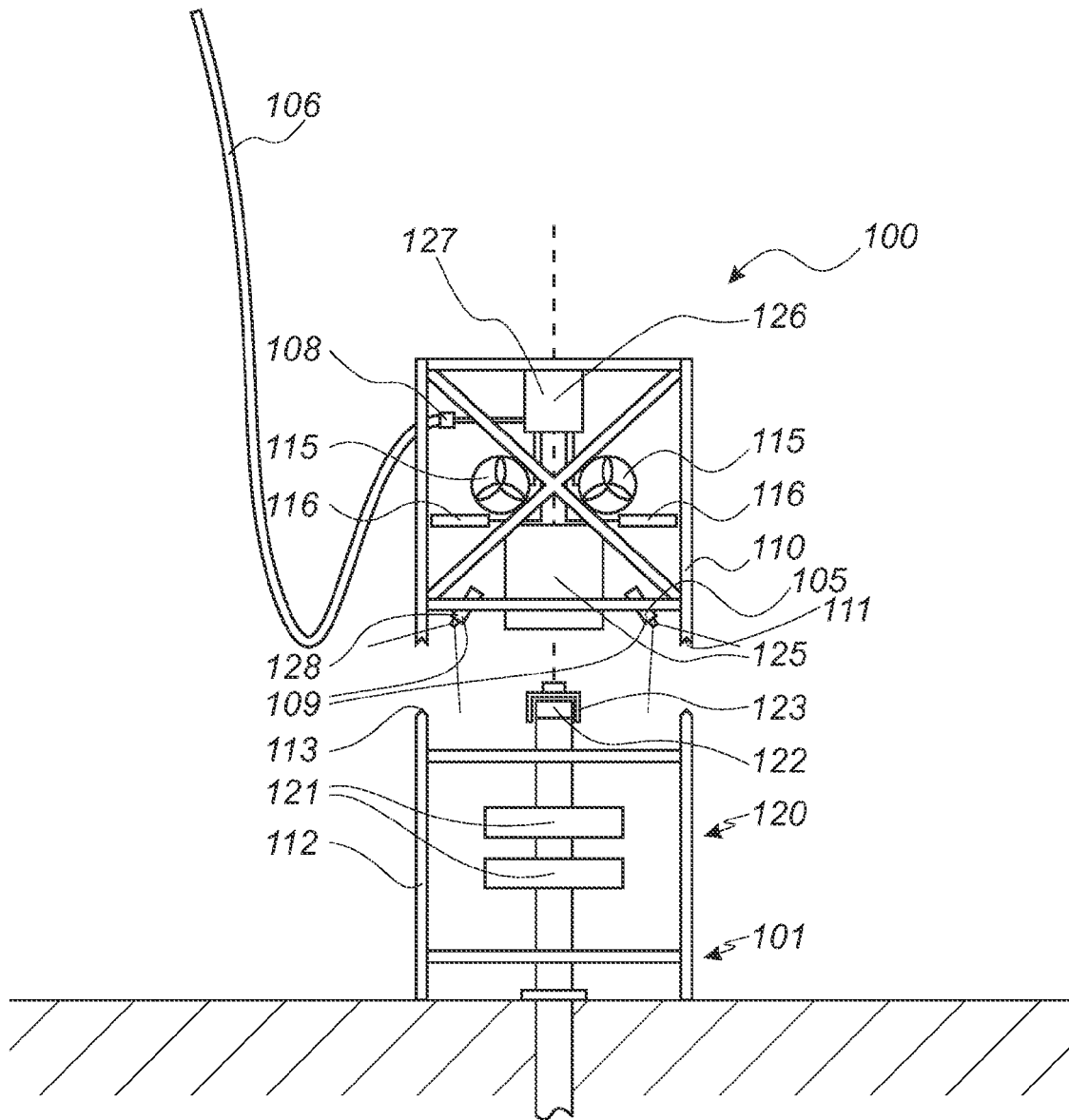


Fig. 2

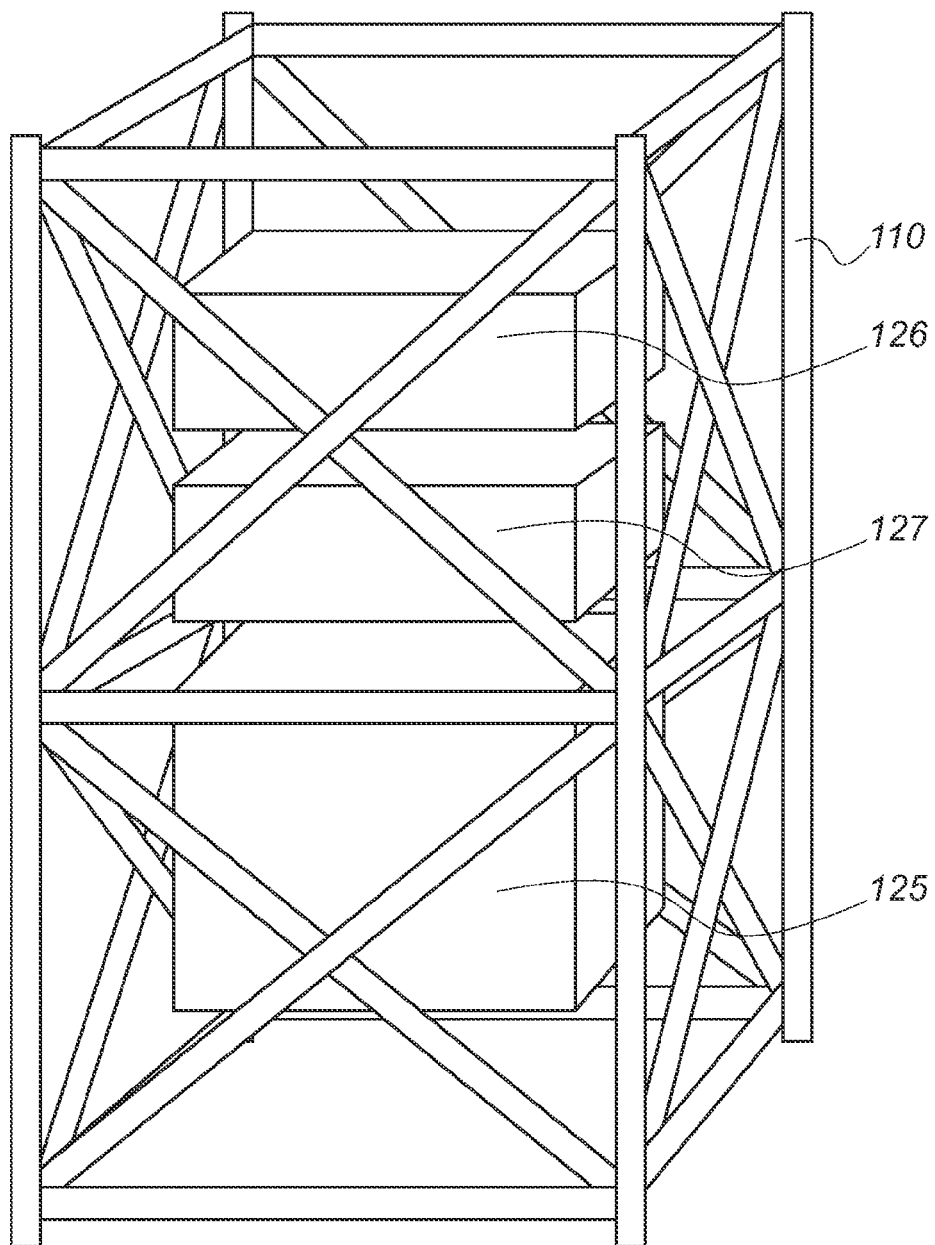


Fig. 3

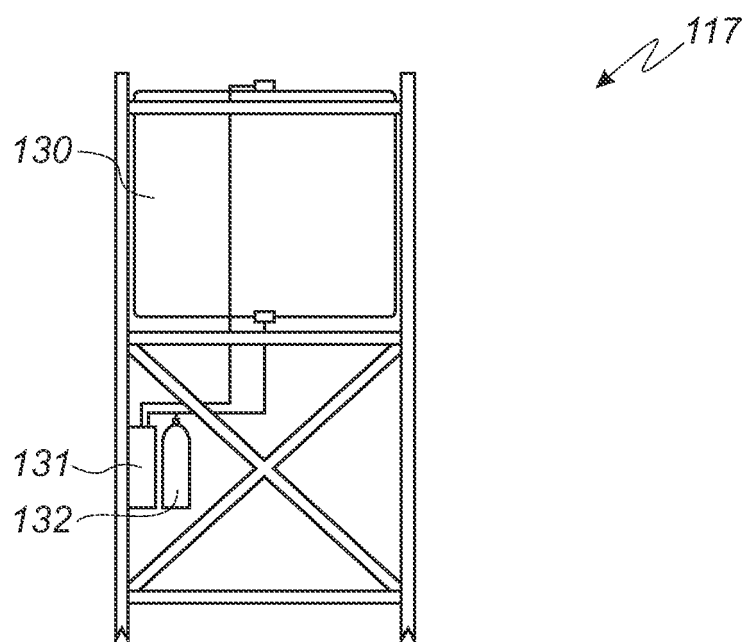


Fig. 4

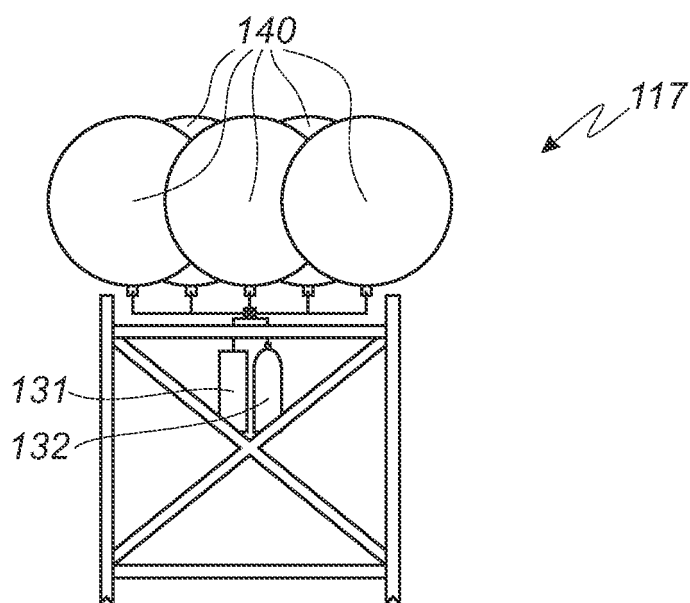


Fig. 5

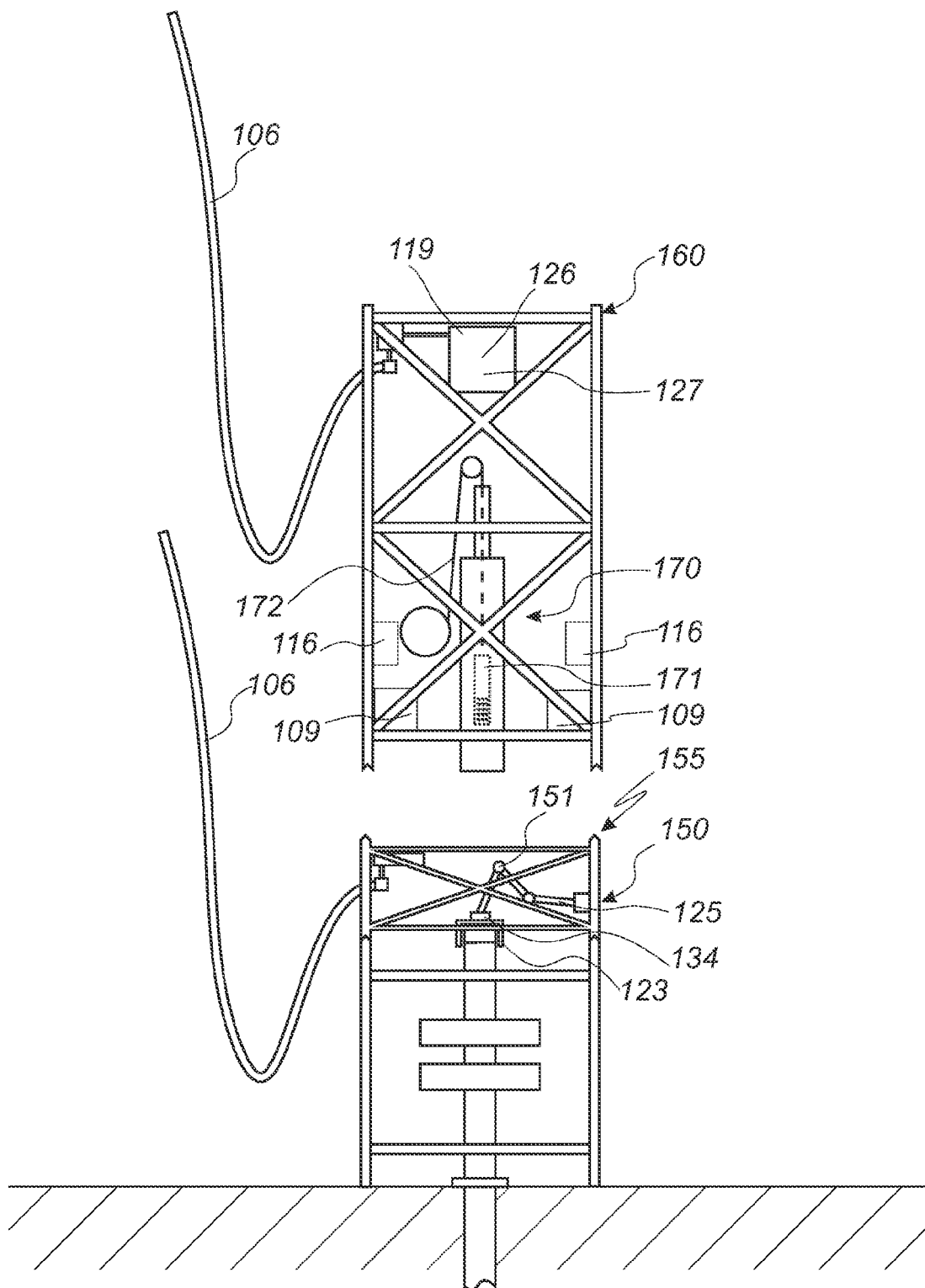


Fig. 6

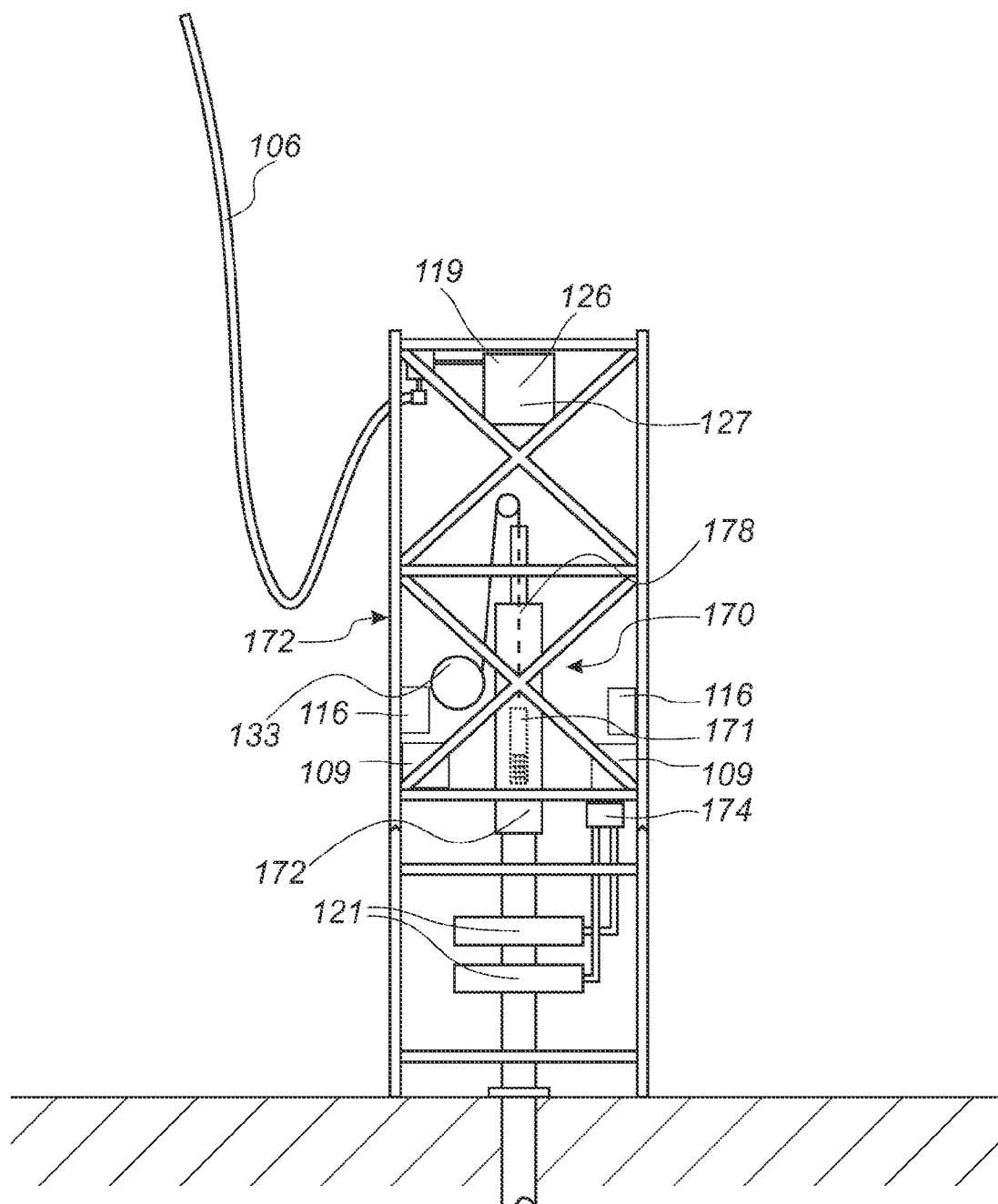


Fig. 7

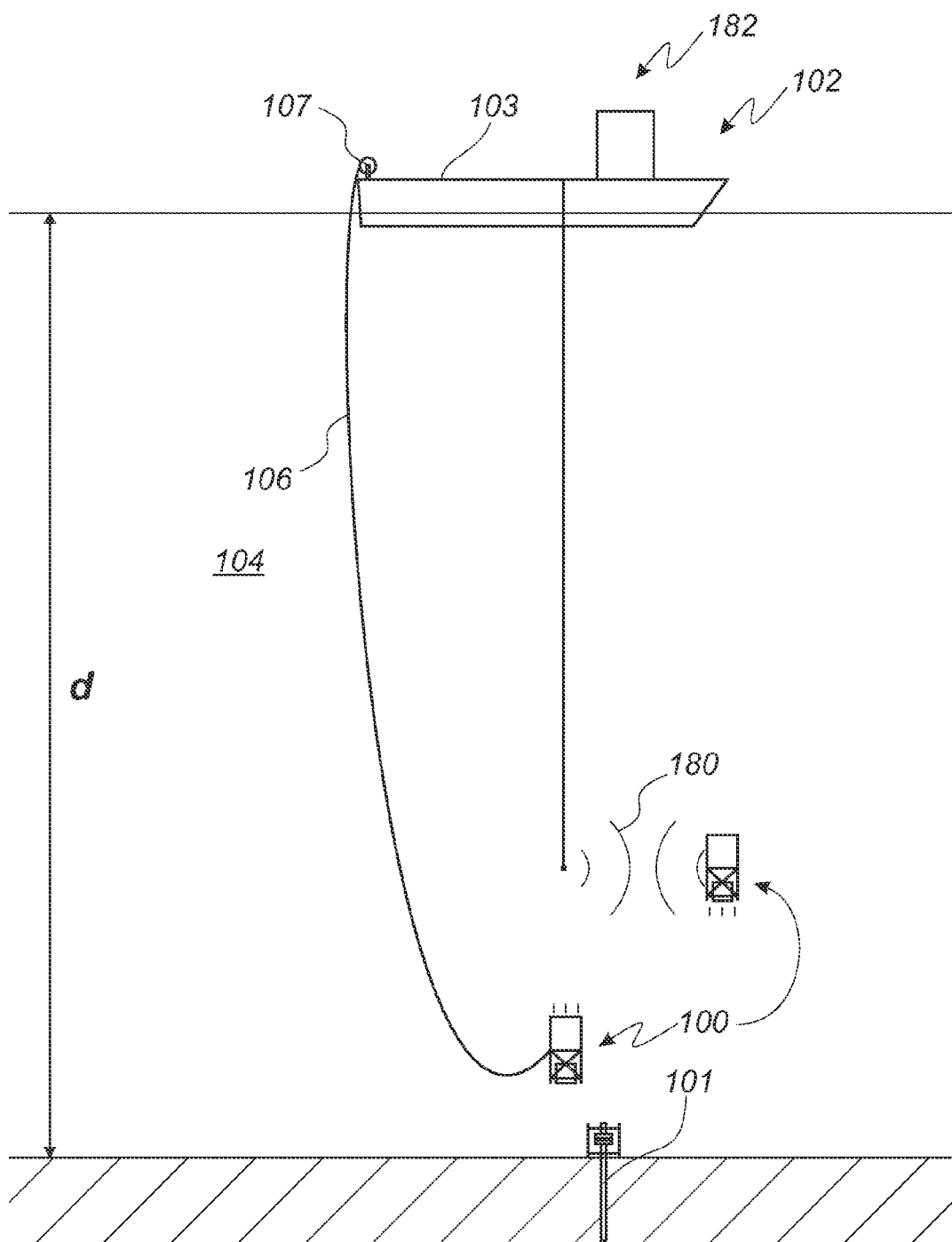


Fig. 8

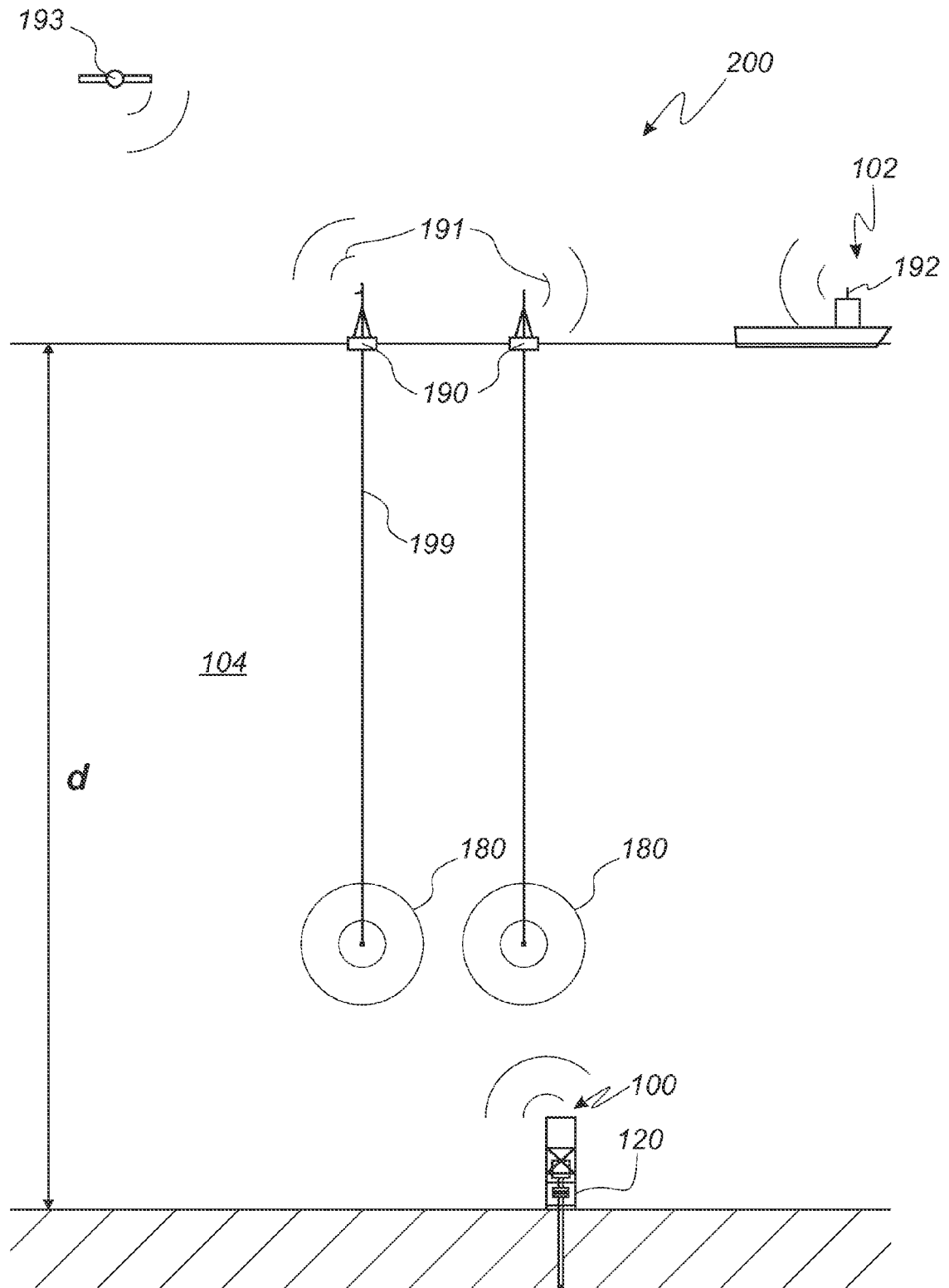


Fig. 9

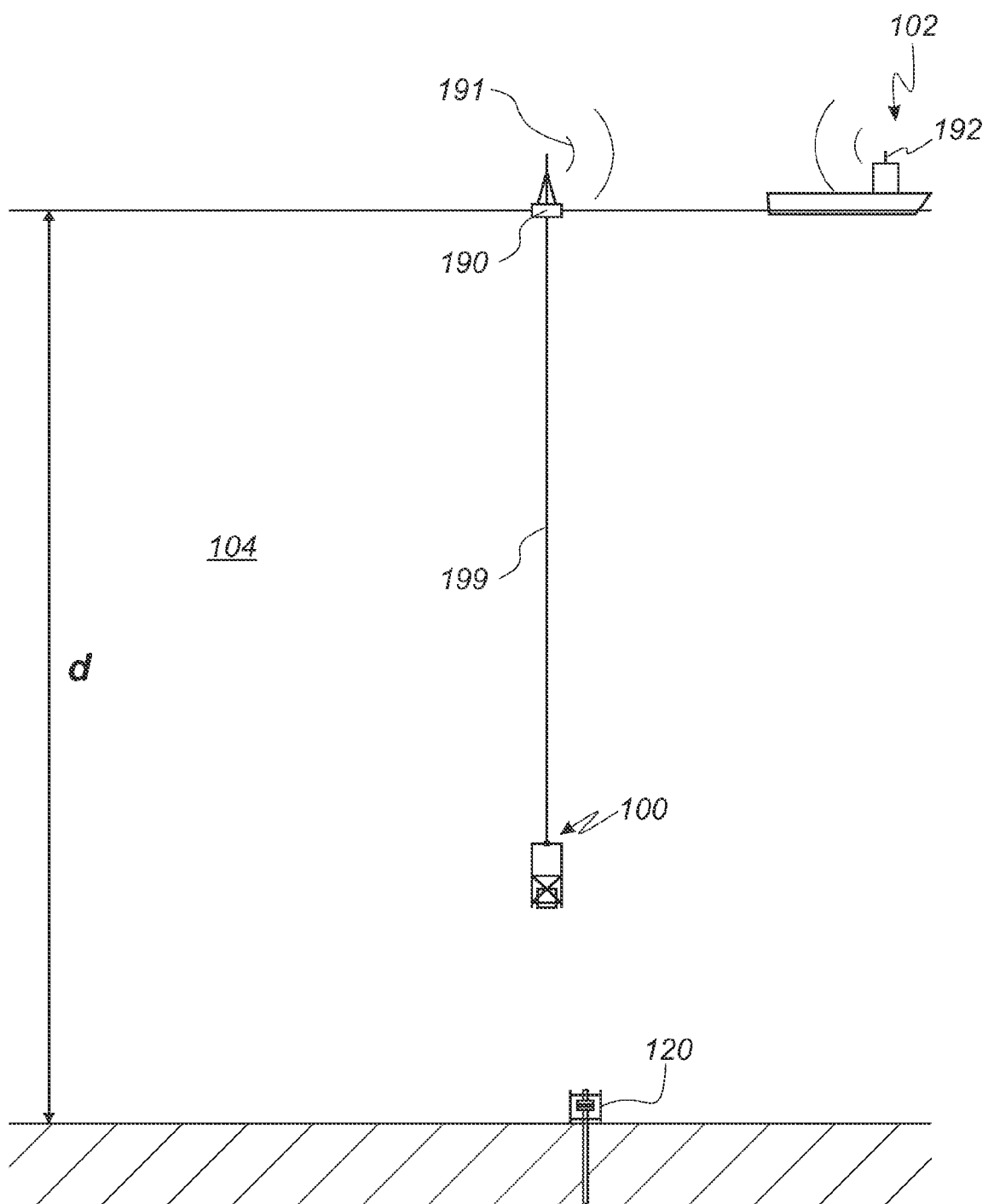


Fig. 10



EUROPEAN SEARCH REPORT

 Application Number
 EP 08 17 1591

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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Place of search The Hague		Date of completion of the search 14 January 2010	Examiner Rampelmann, Klaus
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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