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Description**FIELD OF THE INVENTION**

[0001] The invention relates to a method of building an offshore windmill on a windmill pedestal that is located offshore.

BACKGROUND OF THE INVENTION

[0002] Offshore wind energy is becoming more and more important. In particular the last couple of years there has been an enormous increase in the number of wind farms (a grid of windmills placed on the continental shelf in the seas). Not only is the number of offshore windmills increasing, but also their size, i.e. the windmills are getting bigger. The latter brings new challenges in terms of actually installing these offshore windmills. Dedicated huge ships have been built having very large heavy duty cranes placed on top of them. The general idea is to manufacture the windmills onshore in as large parts as possible and then transport these parts to the desired location, where they are placed using the ever-increasing heavy-duty cranes on an earlier prepared offshore windmill pedestal. There exists a huge variety of different technologies of preparing and building such windmill pedestals offshore, but that is beyond the scope of this invention. As the size of the offshore windmills increases further, also the size of these dedicated windmill installation ships is increasing. In order to facilitate the use of a huge crane these ships are provided with a jack-up system such that they lift themselves out of the sea, which makes the ships orientation independent of the waves. It is particularly the operational costs of these ships, which is of concern.

[0003] In the prior art some suggestions are reported to resolve this issue.

[0004] GB2,365,905A discloses an offshore structure comprising a watertight chamber having a base, which rests on the seabed and a telescopically extendable shaft, which extends upwardly from the chamber, with a hoist located at the shaft top. A wind turbine may be located at the top of the shaft, while a generator may be located in the base. The structure may be towed floating with the column retracted to its installation point, where the base is then ballasted to its resting position on the seabed. The column may then be extended and grouted in place, while the hoist may be used to raise the rotor hub and blades to the required position at the top of the column.

[0005] WO2010/151145A1 discloses a windmill comprising a generator house with a generator (also being referred to as "nacelle") and a plurality of rotor blades at an upper part of an upright shaft. Said shaft comprises at least one telescopic joint for altering the height of said windmill, and further comprises a pivotal connection of the blades between a substantially vertical and a substantially horizontal position. The respective disclosure

relates to a method of installation, intervention or decommissioning of said windmill. It finds application to fixed, bottom mounted offshore windmills or onshore windmills. Other prior art examples can be found in WO03100248 and DE10111280.

[0006] A first disadvantage of the above-presented windmills and installation methods is that they are not retrofit solutions, i.e. they cannot be applied to existing offshore windmill pedestals. In addition, said methods and windmills are not easily scaled up. Thus, there is a need for a further improved retrofit method of building offshore windmills.

SUMMARY OF THE INVENTION

[0007] The invention has for its object to remedy or to reduce at least one of the drawbacks of the prior art, or at least provide a useful alternative to prior art.

[0008] The object is achieved through features, which are specified in the description below and in the claims that follow.

[0009] The invention is defined by the independent patent claims. The dependent claims define advantageous embodiments of the invention.

[0010] In a first aspect the invention relates to a method of building an offshore windmill on a windmill pedestal that is located offshore. The method comprises:

- providing a floating vessel comprising a 3D-heave-compensated crane on a deck thereof;
- providing at least one offshore windmill assembly and a lifting jack, wherein the offshore windmill assembly comprises a windmill generator, a plurality of windmill blades and at least two windmill column parts for forming a windmill column at a later stage, wherein the lifting jack is configured for receiving the windmill column in a receiving region thereof;
- moving said floating vessel, the lifting jack and the at least one offshore windmill assembly in proximity of the windmill pedestal;
- placing the lifting jack directly on the windmill pedestal using the 3D-heave-compensated crane and fixing the lifting jack to the windmill pedestal such that it can be later removed, and wherein the lifting jack is fixed to the windmill pedestal such that the windmill column can be placed within the receiving region directly on the windmill pedestal;
- installing the windmill generator using the 3D-heave-compensated crane;
- partially erecting the windmill column on the windmill pedestal using the 3D-heave-compensated crane and the lifting jack;
- installing the windmill blades on the windmill generator using the 3D-heave-compensated crane at a stage where the windmill column has been partially erected;
- fully erecting the windmill column on the windmill pedestal using at least the lifting jack, and

- removing the lifting jack from the windmill pedestal using the 3D-heave-compensated crane.

[0011] In order to facilitate understanding of the invention one or more expressions are further defined herein-after.

[0012] The effects of the method in accordance with the invention are as follows.

[0013] The first important feature of the invention is that a floating vessel is provided having a 3D-heave-compensated crane. Throughout this specification the wording "3D-heave-compensated crane" refers to a crane, which has a system in place for keeping the load of the crane substantially free of movement due to waves in all three dimensions. Expressed differently, it refers to a crane having heave-compensation for the three position degrees of freedom of the load. In addition, there might even be heave-compensation for one or more rotation degrees of freedom, but that is not essential to the invention. As mentioned in the background of the invention often very large dedicated jack-up ships having very large cranes are used. By providing a 3D-heave compensated crane, it is rendered possible to use much smaller main-stream vessels, such as standard offshore crane vessels.

[0014] Another feature of the invention is that the offshore windmill is shipped towards the windmill pedestal in parts. The offshore windmill parts and the lifting jack may be shipped on the same vessel (having the crane) or on (a) different vessel(s). Important to note is that the windmill pedestal does not need to be substantially altered for facilitating the building of the windmill, i.e. the solution is fully retrofit. In the prior art solutions discussed in the background section special pedestal constructions are required to enable the suggested solutions.

[0015] A third feature of the invention is that a temporary lifting jack is provided, which means that the lifting jack is first added to the structure (that is directly on the windmill pedestal, or on the pedestal adapter if this one has been installed on the windmill pedestal first) and later removed after the building of the offshore windmill is finished. The lifting jack plays an important role in the actual building of the offshore windmill as will be more obviated in the detailed description of the figures.

[0016] A further feature is that the respective parts (the windmill generator, the windmill column (parts) and the windmill blades) of the offshore windmill are brought to the windmill pedestal one after the other, wherein the order of these parts is cleverly chosen to facilitate the building of the windmill in an efficient way and using a crane, which is much smaller than the existing cranes that are used for a windmill of a similar size. One of the reasons is that parts like the windmill generator and the windmill blades are installed before the windmill column is fully erected. Expressed differently, the windmill column is effectively erected to its final height after installation of these parts. Another reason is that the windmill column is partially erected before the windmill blades are installed. This allows for vertical installation, without the

need for special hinge constructions as is the case in one of the prior art solutions. Another reason is that the windmill column is built on top of the pedestal without altering it.

[0017] It must be stressed that the amount of variations concerning the order of method steps is very large and that by no means the order as mentioned in claim 1 must be construed as limiting the claim. All variations in order are considered to fall within the scope of the invention, unless such order would result in something unfeasible.

[0018] In an embodiment of the method in accordance with the invention the method further comprises, before the step of placing the lifting jack, a step of preparing the windmill pedestal for receiving the lifting jack, for instance by placing a pedestal adaptor on the windmill pedestal. The lifting jack must be fixed to the windmill pedestal such that it hangs or stands on it, and in this embodiment that is done via the pedestal adaptor. However, it is also possible to modify the lifting jack such that it can be removably mounted to the pedestal, i.e. rendering the pedestal adaptor superfluous.

[0019] In an embodiment of the method in accordance with the invention, in the step of installing the windmill generator, the windmill generator is installed on the lifting jack. This embodiment is very advantageous, because it facilitates the provision of the windmill generator very early in the building process. The lifting jack may be in retracted or extended position, when placing the windmill generator. Each of these positions has their own advantages. More information will be given in the detailed description of the figures.

[0020] In an embodiment of the method in accordance with the invention, in the step of partially erecting the windmill column, at least a first one of the at least two windmill column parts is installed on the windmill pedestal, and, in the step of fully erecting the windmill column, the remaining ones of the windmill column parts are installed using the lifting jack for creating room between the windmill pedestal and the remaining part of the windmill column, as well as using the 3D-heave-compensated crane for moving the respective windmill column parts from the floating vessel to the pedestal. This embodiment constitutes a first main variant of building up the windmill column from bottom to top.

[0021] There is a great freedom in terms of the stage of the method, wherein the first windmill column part is installed. In a first variant, this first part of the windmill column may be installed even before placement of the lifting jack, such that the lifting jack is to be placed over or around the first column part. In a second variant, this first part of the windmill column may be installed between the placement of the lifting jack and the installing of the windmill generator, wherein the windmill generator is then to be placed on the first column part. In a third variant, this first part of the windmill column may be installed after installing of the windmill generator, but then the lifting jack must be extended to create the place between the windmill pedestal and the windmill generator. It is not

unlikely that more variants are found by the person skilled in the art just using his normal routine and expertise.

[0022] In an embodiment of the method in accordance with the invention, in the step of providing the floating vessel, the at least two windmill column parts that are provided on the floating vessel are in the form of a telescopic windmill column in its retracted state. This embodiment facilitates faster building of the offshore windmill, but also the building of higher windmills, in particular when a plurality of telescopic windmill column parts are provided.

[0023] In an embodiment of the method in accordance with the invention, in the step of partially erecting the windmill column, the telescopic windmill column is installed in its retracted state on the windmill pedestal, and, in the step of fully erecting the windmill column, the lifting jack is used to extend the telescopic windmill column. This embodiment builds further on the previously-mentioned embodiment and constitutes a second main variant of building up the windmill column from bottom to top. In case the telescopic windmill column comprises more than two parts, the extension of the column can be done using multiple runs of the lifting jack. In each next run, the lifting jack is fixed to a different one of the respective parts of the telescopic column, until all respective parts of the telescopic column have been extended and the telescopic column has reached its maximum length. More information will be given in the detailed description of the figures.

[0024] It must be stressed that the first and second main variant of building up the windmill column may also be combined, in that the column is build up out of a telescopic part in combination with one or more further parts, or even one or more further telescopic parts. The lifting jack of the invention may be conveniently used to lift up/extend these telescopic parts and further telescopic parts one after the other.

[0025] In an embodiment of the method in accordance with the invention, in the step of installing the windmill blades, the windmill blades are installed sequentially, wherein the windmill generator is used to manipulate a position of a windmill hub of the windmill generator such that the respective windmill blade can be easily mounted thereto, preferably in its vertical downward-pointing direction. This embodiment facilitates the use of a smaller crane to mount the windmill blades or the building of larger windmills using the same crane size.

[0026] In an embodiment of the method in accordance with the invention, in the step of providing the floating vessel, the floating vessel is provided with an enhanced lifting jack that further comprises a cradle that is configured for i) receiving respective windmill parts, for ii) bringing said parts from a lower end of the lifting jack to an upper end of lifting jack for iii) manipulating, i.e. rotating, said parts to a vertical position, where necessary, and for iv) bringing said parts to said receiving region. This embodiment facilitates the building of even larger windmills as the enhanced lifting jack partially takes over the

function of the crane. The main thing the crane needs to do in this embodiment is to put the respective parts on the cradle, while most of the other operations are carried out by the cradle. The enhanced lifting jack is explained in more detail in the detailed description of the figures.

BRIEF INTRODUCTION OF THE DRAWINGS

[0027] In the following is described examples of embodiments illustrated in the accompanying drawings, wherein:

Figs. 1 to 25 show different stages of an embodiment of the method of building an offshore windmill in accordance with the invention;

Fig. 26a shows a top view of an embodiment of an advanced lifting jack in accordance with the invention, wherein the lifting jack is in an open position;

Fig. 26b shows a top view of the lifting jack of Fig. 26a, wherein the lifting jack is in a closed position; and

Fig. 27 shows a more detailed top view of the lifting jack of Fig. 26b, wherein the cradle is swung from an outer position to a centre position.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0028] Various illustrative embodiments of the present subject matter are described below. In the interest of clarity, not all features of an actual implementation are described in this specification. It will of course be appreciated that in the development of any such actual embodiment, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which will vary from one implementation to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking for those of ordinary skill in the art having the benefit of this disclosure.

[0029] The present subject matter will now be described with reference to the attached figures. Various systems, structures and devices are schematically depicted in the drawings for purposes of explanation only and so as to not obscure the present disclosure with details that are well known to those skilled in the art. Nevertheless, the attached drawings are included to describe and explain illustrative examples of the present disclosure. The words and phrases used herein should be understood and interpreted to have a meaning consistent with the understanding of those words and phrases by those skilled in the relevant art. No special definition of a term or phrase, i.e., a definition that is different from the ordinary and customary meaning as understood by those skilled in the art, is intended to be implied by consistent usage of the term or phrase herein. To the extent that a term or phrase is intended to have a special mean-

ing, i.e., a meaning other than that understood by skilled artisans, such a special definition will be expressly set forth in the specification in a definitional manner that directly and unequivocally provides the special definition for the term or phrase.

[0030] Figs. 1 to 25 show different stages of an embodiment of the method of building an offshore windmill in accordance with the invention. Fig. 1 shows a first stage of this method. In this stage of the method there is provided a floating vessel 900, for instance an offshore crane ship. The vessel 900 has been provided with a 3D-heave compensated crane 910 on a deck 901 thereof. The 3D-heave compensated crane 910 is capable of lifting between 250T or 400T, for example. It is typically the windmill generator (nacelle), which is the heaviest part of the windmill assembly. A 6MW nacelle/windmill generator (i.e. from RePower) typically weighs 316T, so a 400T crane will be able of installing most 6MW nacelles and some 8MW nacelles. A 5MW nacelle (i.e. from Multi-bird) typically weighs 233T, so a 250T crane will be able to install most nacelle designs up to and including 5MW.

[0031] The vessel 900 is provided with offshore windmill parts, including a plurality of windmill column parts 110, a windmill generator 120, and a plurality of windmill blades 130. It must be noted that there may be a collection of other smaller parts, which is needed for mounting, fixing and installing the parts together, but all these details have been omitted in order not to obscure the invention. In Fig. 1 the vessel 900 has transported the windmill parts close to an offshore windmill pedestal 50 in a sea 1, so close that the pedestal is within reach of the crane 910. In addition to the windmill parts the vessel 900 is also provided with a lifting jack 90, which plays an important role in the method of the invention. In the embodiment shown of Figs. 1 to 25, the pedestal 50 has been provided with a so-called pedestal adaptor 51, which serves to cooperate with the lifting jack 90 as will be explained later.

[0032] Fig. 2 shows another stage of the method of building an offshore windmill. In this stage of the method, the lifting jack 90 is placed directly on the pedestal 50 using the crane 910. The load on the crane is typically in the order of 200T (depending on the size of the windmill that is built) and is lifted and moved to the pedestal 50 in 3D-advanced heave compensation (3D-AHC) mode. The lifting jack 90 comprises fixing members 91, which facilitate placing and fixing the lifting jack 90 to the pedestal 50 via the pedestal adaptor 51. It must be noted that there exist also other ways of temporarily mounting a lifting jack 90 to an existing pedestal 50, which may render the pedestal adaptor 51 superfluous. In the figure there is two lifting legs 90-1, 90-2 visible, but in this embodiment there are three, as will be discussed with respect to Figs. 26-27. The lifting jack 90 further comprises a cradle 95 mounted to one of its lifting legs 90-1. As will be further explained with reference to other figures this cradle 95 is used to lift windmill parts up to the upper end of the lifting jack 90, but also to manipulate the orientation of said parts to facilitate the building of the windmill. The

cradle 95 is configured to slide along the respective lifting leg 90-1.

[0033] Fig. 3 shows another stage of the method of building an offshore windmill. In this stage of the method, the windmill generator 120 is lifted and moved to the pedestal 50 using the crane 910 in 3D-AHC mode. The typical load on the crane 910 is 200-300T, depending on the size of the windmill that is built. In this embodiment the windmill generator 120 is secured (i.e. bolted) to the top side of the lifting jack 90 as illustrated.

[0034] Fig. 4 shows another stage of the method of building an offshore windmill. In this stage of the method a first one 110-1 of the three windmill column parts 110-1, 110-2, 110-3 is lifted with the crane 910. The typical load on the crane 910 is 70-100T, depending on the size of the windmill that is built.

[0035] Fig. 5 shows another stage of the method of building an offshore windmill. In this stage of the method, the lifting jack 90 is run up to its top position. In addition, the cradle 95 is moved towards a position in between the two extreme positions (maximum extension and minimum extension) as illustrated.

[0036] The stages of Figs. 4 and 5 can be easily exchanged, i.e. the lifting jack 90 can be run up before the first windmill column part 110-1 is lifted up by the crane 910.

[0037] Fig. 6 shows another stage of the method of building an offshore windmill. In this stage of the method the first windmill column part 110-1 is moved to and placed on the cradle 95 (also referred to as catwalk) of the lifting jack 90 using the crane 910 in 3D-AHC mode.

[0038] Fig. 7 shows another stage of the method of building an offshore windmill. In this stage of the method the first windmill column part 110-1 is clamped by the cradle 95 and rotated to a vertical position. More details about the cradle 95 to facilitate this are given with reference to Figs. 26-27.

[0039] Fig. 8 shows another stage of the method of building an offshore windmill. In this stage of the method the cradle 95 rotates around the respective lifting leg 90-1 to which it is mounted swinging the respective first windmill column part 110-1 to the centre region of the lifting jack 90 in between the pedestal 50 and the windmill generator 120. Furthermore, the windmill generator 120 has been landed on the first windmill column part 110-1 by letting the lifting jack 90 descend a little bit. Subsequently, the windmill generator 120 has been secured to the respective windmill tower part 110-1.

[0040] Fig. 9 shows another stage of the method of building an offshore windmill. In this stage of the method, the first windmill column part 110-1 has been released and the cradle 95 has been swung outward to the outside region as illustrated. Furthermore, the lifting jack 90 has been further lowered until the first windmill column part 110-1 has landed on the pedestal 50. The first column part 110-1 has been temporarily secured to the pedestal 50, i.e. it will be detached from it at a later stage of the method. Finally, the lifting jack 90 has been released from

the windmill generator 120 and lowered as illustrated.

[0041] Fig. 10 shows another stage of the method of building an offshore windmill. In this stage of the method, a first one 130-1 of three windmill blades 130-1, 130-2, 130-3 is lifted using the crane 910 in 3D-AHC mode. The load on the crane in this stage is typically in the order of 15-35T depending on the size of the windmill.

[0042] Fig. 11 shows another stage of the method of building an offshore windmill. In this stage of the method, the first windmill blade 130-1 is moved to and placed on the cradle 95 using the crane 910 in 3D-AHC mode.

[0043] Fig. 12 shows another stage of the method of building an offshore windmill. In this stage of the method, the first windmill blade 130-1 has been secured to (clamped by) the cradle 95 and rotated to a vertical position as illustrated. Subsequently the cradle 95 is moved up so that the first windmill blade 130-1 is touching the hub 121 of the windmill generator 120. The first windmill blade 130-1 is then mounted to the hub 121.

[0044] Fig. 13 shows another stage of the method of building an offshore windmill. In this stage of the method, the cradle 95 is opened (releasing the first windmill blade 130-1) and rotated back to its horizontal position. Furthermore, a second one 130-2 of the three windmill blades is lifted using the crane 910 in 3D-AHC mode. The load on the crane in this stage is typically in the order of 15-35T depending on the size of the windmill. In addition, the hub 121 of the windmill generator 120 is rotated 120 degrees.

[0045] Fig. 14 shows another stage of the method of building an offshore windmill. In this stage of the method, the second windmill blade 130-2 is mounted to the hub 121 in a similar way as illustrated in Figs. 11 to 13.

[0046] Fig. 15 shows another stage of the method of building an offshore windmill. In this stage of the method, the third windmill blade 130-3 is mounted to the hub 121 in a similar way as illustrated in Figs. 11 to 13.

[0047] Fig. 16 shows another stage of the method of building an offshore windmill. In this stage of the method, the propeller is complete and the windmill generator 120 (also called Nacelle) is rotated 180 degrees around the pedestal axis 50a, such that the propeller of the windmill generator 120 is facing away from the vessel 900. This step creates the space for the further part of installation process, i.e. it substantially frees the cradle 95 of the lifting jack 90 for further lifting operations.

[0048] Fig. 17 shows another stage of the method of building an offshore windmill. In this stage the second windmill column part 110-2 is lifted from the vessel 900 using the crane 910 in 3D-AHC mode. The typical load on the crane 910 is 70-100T, depending on the size of the windmill that is built. The cradle 95 is opened (its clamping arm is released and moved away) and moved to a lower end of the lifting jack 90.

[0049] Fig. 18 shows another stage of the method of building an offshore windmill. In this stage of the method, the first windmill column part 110-1 is fixed to the lifting jack 90 and subsequently detached from the pedestal

50. The lifting jack 90 has been subsequently lifted (extended) and the cradle 95 is moved to a location in between said two end positions. Finally, the second windmill column part 110-2 has been moved to and placed on the cradle 95 using the crane 910 in 3D-AHC mode, which is then locked and rotated 90 degrees to bring the second windmill column in a vertical position.

[0050] Fig. 19 shows another stage of the method of building an offshore windmill. In this stage of the method, the second windmill column part 110-2 has been rotated with the cradle 95 towards the centre region of the lifting jack 90 in between the pedestal 50 and the first windmill column part 110-1.

[0051] Fig. 20 shows another stage of the method of building an offshore windmill. In this stage of the method, the second windmill column part 110-2 is secured to the first windmill column part 110-1, and temporarily secured to the pedestal 50. Subsequently, the lifting jack 90 is retracted.

[0052] Fig. 21 shows another stage of the method of building an offshore windmill. In this stage of the method, the lifting jack 90 has been coupled to a lower end of the second windmill column part 110-2, and the second windmill column part 110-2 has been subsequently detached from the pedestal 50. Finally, the lifting jack 90 is lifted to its maximum height, the third windmill column part 130-3 has been lifted, moved to and placed in the cradle 95 (using the crane 910 in 3D-AHC mode), locked, and rotated, similar to as discussed with reference to previous figures.

[0053] Fig. 22 shows another stage of the method of building an offshore windmill. In this stage of the method, the third windmill column part 110-3 has been rotated with the cradle 95 towards the centre region of the lifting jack 90 in between the pedestal 50 and the second windmill column part 110-2. The third windmill column part 110-3 is secured to the second windmill column part 110-2, and to the pedestal 50.

[0054] Fig. 23 shows another stage of the method of building an offshore windmill. In this stage of the method, the lifting jack 90 has been retracted, detached from the windmill, and is about to be removed (lifted up) by the crane 910 in 3D-AHC mode. The load on the crane 910 is typically in the order of 200T (depending on the size of the windmill that is built).

[0055] Fig. 24 shows another stage of the method of building an offshore windmill. In this stage of the method, the lifting jack 90 has been removed and placed on the vessel 900 by the crane 910. Subsequently, the lifting jack 90 is to be prepared for the next windmill.

[0056] Fig. 25 shows another stage of the method of building an offshore windmill. In this stage of the method, the offshore windmill 100 has been completed.

[0057] It has already been mentioned that in an advantageous embodiment of the method of the invention an enhanced lifting jack 90 is provided, having extra functionality besides the basic jacking function. This enhanced lifting jack 90 comprises a cradle 95 that is con-

figured for i) receiving respective windmill parts, for ii) bringing said parts (in a horizontal position) from a lower end of the lifting jack to an upper end of lifting jack for iii) manipulating, i.e. rotating, said parts to a vertical position, where necessary, and for iv) bringing said parts to said receiving region. It has to be noted that the cradle 95 is advantageous, but not essential to the invention. Its function could be taken up by the crane, albeit that the crane then needs to be modified such that it can handle, hold and manipulate parts. Expressed differently, the crane needs to be turned into some sort of robot arm.

[0058] Fig. 26a shows a top view of an embodiment of the advanced lifting jack 90 in accordance with the invention, wherein the lifting jack is in an open position. Fig. 26b shows a top view of the lifting jack of Fig. 26a, wherein the lifting jack is in a closed position. In these figures it is illustrated how the lifting jack 90 can be folded around an existing tubular structure if necessary. These figures also serve to illustrate how the earlier discussed fixing members 91 can be placed on the pedestal adaptor 51 as illustrated. The cradle 95 in this embodiment comprises effectively two receiving members 95-2 in order to receive the parts in a stable manner.

[0059] Fig. 27 shows a more detailed top view of the lifting jack of Fig. 26b, wherein the cradle 95 is swung from an outer position to a centre position. A first feature that is illustrated in Fig. 27 are the locking members 96 that cooperate with the receiving members 95-1, 95-2 for holding/clamping respective parts. It must be noted that in Fig. 27 the cradle 95 in Fig. 27 has been rotated 90 degrees (for manipulating the respective part to a vertical position). Furthermore, the cradle 95 has been illustrated in four different swing positions, wherein it is visible that the cradle 95 may effectively swing in between said first 90-1 and third lifting leg 90-3 of the lifting jack 90 towards the centre region.

[0060] The method as illustrated in Figs. 1 to 26 is just one of the many possible embodiments. There are many variations on the embodiments possible, which has been extensively discussed in the introduction of this specification.

[0061] In a further variation there is no cradle 95 on the lifting jack 90 as discussed with regards to Figs. 26a, 26b and 27 earlier.

[0062] For instance, it must be noted that the lifting jack 90 in Fig. 2 may be provided after provision of the first windmill column part 110-1. As illustrated in Figs. 26a and 26b the lifting jack may be simply folded around the windmill column part and land on the pedestal adaptor 51 with its fixing members.

[0063] Furthermore, the windmill generator 120 in Fig. 3 may also be placed later, i.e. after provision of the first windmill column part 110-1. In that case it may be directly mounted on the first windmill column part 110-1 instead of on the lifting jack 90. Alternatively, the windmill generator 120 in Fig. 3 may be placed on an already lifted (extended) lifting jack 90, even if no windmill column part 110-1 is placed underneath.

[0064] In addition, the windmill column parts 110-1..110-3 may be partially replaced by (a) telescopic windmill column (part(s)). The lifting jack 90 may be conveniently used to sequentially extend the telescopic column parts.

[0065] Alternatively, the windmill blades 130-1..130..3 in Figs. 10 to 16 may be installed after installation of two or more windmill column parts 110-1..110-3. On one side this means that the crane may need to reach higher or be larger, while on the other side this allows for the installation of larger windmill blades.

[0066] The particular embodiments disclosed above are illustrative only, as the invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. For example, the method steps set forth above may be performed in a different order. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular embodiments disclosed above may be altered or modified and all such variations are considered within the scope of the invention. Accordingly, the protection sought herein is as set forth in the claims below.

[0067] It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. Use of the verb "comprise" and its conjugations does not exclude the presence of elements or steps other than those stated in a claim. The article "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. In the device claim enumerating several means, several of these means may be embodied by one and the same item of hardware.

REFERENCES CITED IN THE DESCRIPTION

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

Patent documents cited in the description

- GB 2365905 A [0004]
- WO 2010151145 A1 [0005]
- WO 03100248 A [0005]
- DE 10111280 [0005]

FREM GANGSMÅDE TIL BYGNING AF EN OFFSHORE-VINDMØLLE

Patentkrav

1. Fremgangsmåde til bygning af en offshore-vindmølle (100) på en vindmøllesokkel (50), der er lokaliseret offshore, **kendetegnet ved, at** fremgangsmåden omfatter:

- tilvejebringelse af et flydende fartøj (900), der omfatter en 3D-hævekompensteret kran (910) på et dæk (901) deraf;
- tilvejebringelse af mindst én offshore-vindmøllesamling (110, 120, 130) og en donkraft (90), hvor offshore-vindmøllesamlingen omfatter en vindmøllegenerator (120), en flerhed af vindmøllevinger (130, 130-1..130-3) og mindst to vindmølletårndele (110, 110-1..110-3) til dannelsen af et vindmølletårn på et senere trin, hvor donkraften (90) er konfigureret til at modtage vindmølletårnet (110-1..110-3) i et modtagelsesområde deraf;
- flytning af det flydende fartøj (900), donkraften (90) og den mindst ene offshore-vindmøllesamling (110, 120, 130) hen i nærheden af vindmøllesoklen (50);
- placering af donkraften (90) direkte på vindmøllesoklen (50) under anvendelse af den 3D-hævekompensterede kran (910) og fastgørelse af donkraften (90) til vindmøllesoklen (50), således at den senere kan fjernes, og hvor donkraften (90) er fastgjort til vindmøllesoklen (50), således at vindmølletårnet (110-1..110-3) kan placeres inden for modtagelsesområdet direkte på vindmøllesoklen (50);
- montering af vindmøllegeneratoren (120) under anvendelse af den 3D-hævekompensterede kran (910);
- delvis opstilling af vindmølletårnet (110-1..110-3) på vindmøllesoklen (50) under anvendelse af den 3D-hævekompensterede kran (910) og donkraften (90);
- montering af vindmøllevingerne (130, 130-1..130-3) på vindmøllegeneratoren (120) under anvendelse af den 3D-hævekompensterede kran (910) på et trin, hvor vindmølletårnet (110-1..110-3) er blevet delvist opstillet;
- fuld opstilling af vindmølletårnet (110-1..110-3) på vindmøllesoklen (50) under anvendelse af mindst donkraften (90);

– fjernelse af donkraften (90) fra vindmøllesoklen (50) under anvendelse af den 3D-hævekompenserende kran (910).

2. Fremgangsmåde ifølge krav 1, hvor fremgangsmåden endvidere, inden trinnet med placering af donkraften (90), omfatter et trin med forberedelse af vindmøllesoklen (50) til modtagelse af donkraften (90), for eksempel ved placering af en sokkeladaptor (51) på vindmøllesoklen (50).

3. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, hvor vindmøllegeneratoren (120), i trinnet med montering af vindmøllegeneratoren, monteres på donkraften (90).

4. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, hvor mindst en første af de mindst to vindmølletårndele (110-1), i trinnet med delvis opstilling af vindmølletårnet (110-1..110-3), monteres på vindmøllesoklen (50), og hvor de resterende af vindmølletårndelene (110-2..110-3), i trinnet med fuld opstilling af vindmølletårnet (110-1..110-3), monteres under anvendelse af donkraften med henblik på at skaffe plads mellem vindmøllesoklen (50) og den resterende del af vindmølletårnet (110-1..110-3) samt under anvendelse af den 3D-hævekompenserende kran med henblik på at flytte de tilhørende vindmølletårndele (110-1..110-3) fra det flydende fartøj (900) til soklen (50).

5. Fremgangsmåde ifølge et hvilket som helst af kravene 1 til 3, hvor de mindst to vindmølletårndele (110-1..110-3), i trinnet med tilvejebringelse af det flydende fartøj (900), som er anbragt på det flydende fartøj (900), er i form af et teleskopisk vindmølletårn i tilbagetrukket tilstand.

6. Fremgangsmåde ifølge krav 5, hvor det teleskopiske vindmølletårn, i trinnet med delvis opstilling af vindmølletårnet (110-1..110-3), monteres på vindmøllesoklen (50) i tilbagetrukket tilstand, og hvor donkraften (90), i trinnet med fuld opstilling af vindmølletårnet (110-1..110-3), anvendes til at udstrække det teleskopiske vindmølletårn.

7. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, hvor vindmøllevingerne (130, 130-1..130-3), i trinnet med montering af vindmøllevingerne (130, 130-1..130-3), monteres sekventielt, hvor vindmøllegeneratoren (120) anvendes til at manipulere en position for et vindmøllenav (121) på vindmøllegeneratoren (120), således at den tilhørende vindmøllevinge (130, 130-1..130-3) nemt kan monteres derpå, fortrinsvis i vertikal nedadpegende retning.

8. Fremgangsmåde ifølge et hvilket som helst af de foregående krav, hvor det flydende fartøj, i trinnet med tilvejebringelse af det flydende fartøj (900), er forsynet med en forbedret donkraft (90), der endvidere omfatter et understel (95), som er konfigureret til at i) modtage tilhørende vindmølledele (110-1..110-3, 120, 130-1..130-2), til at ii) bringe delene (110-1..110-3, 120, 130-1..130-2) fra en nedre ende af donkraften (90) til en øvre ende af donkraften (90), til at iii) manipulere, dvs. rotere, delene (110-1..110-3, 120, 130-1..130-2), om nødvendigt, til en vertikal position og til at iv) bringe delene (110-1..110-3, 120, 130-1..130-2) til modtagelsesområdet.

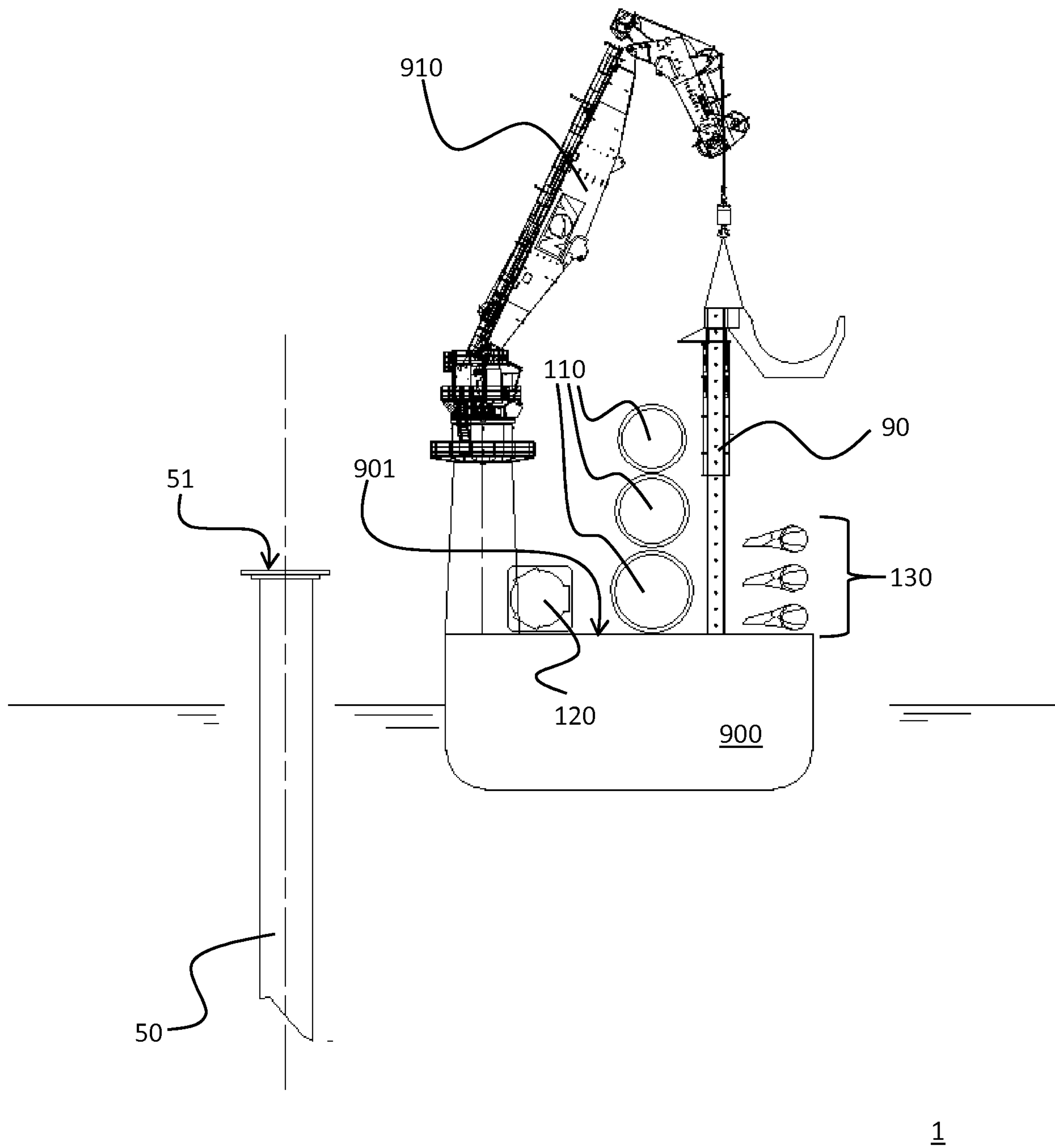


FIG. 1

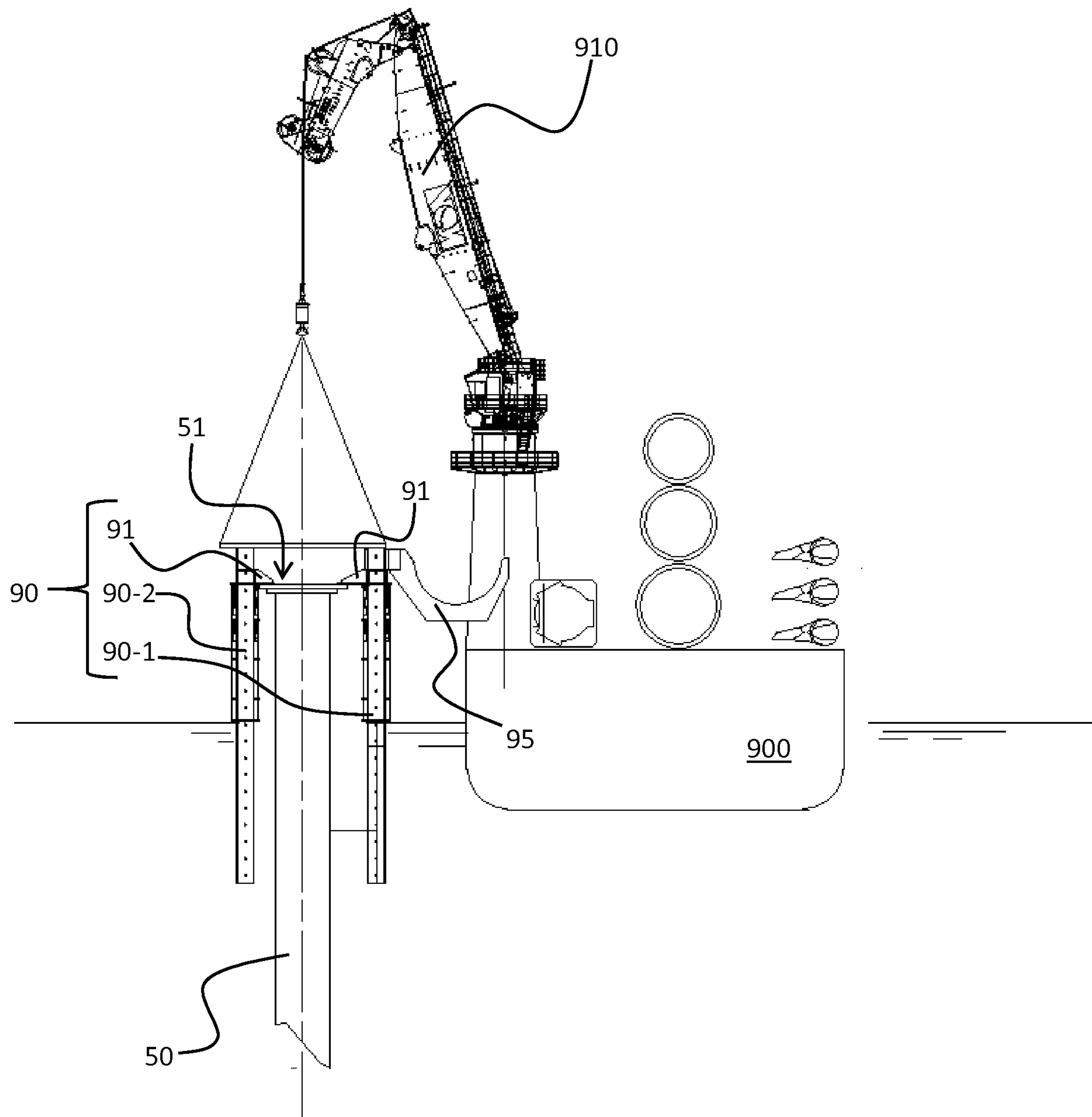


FIG. 2

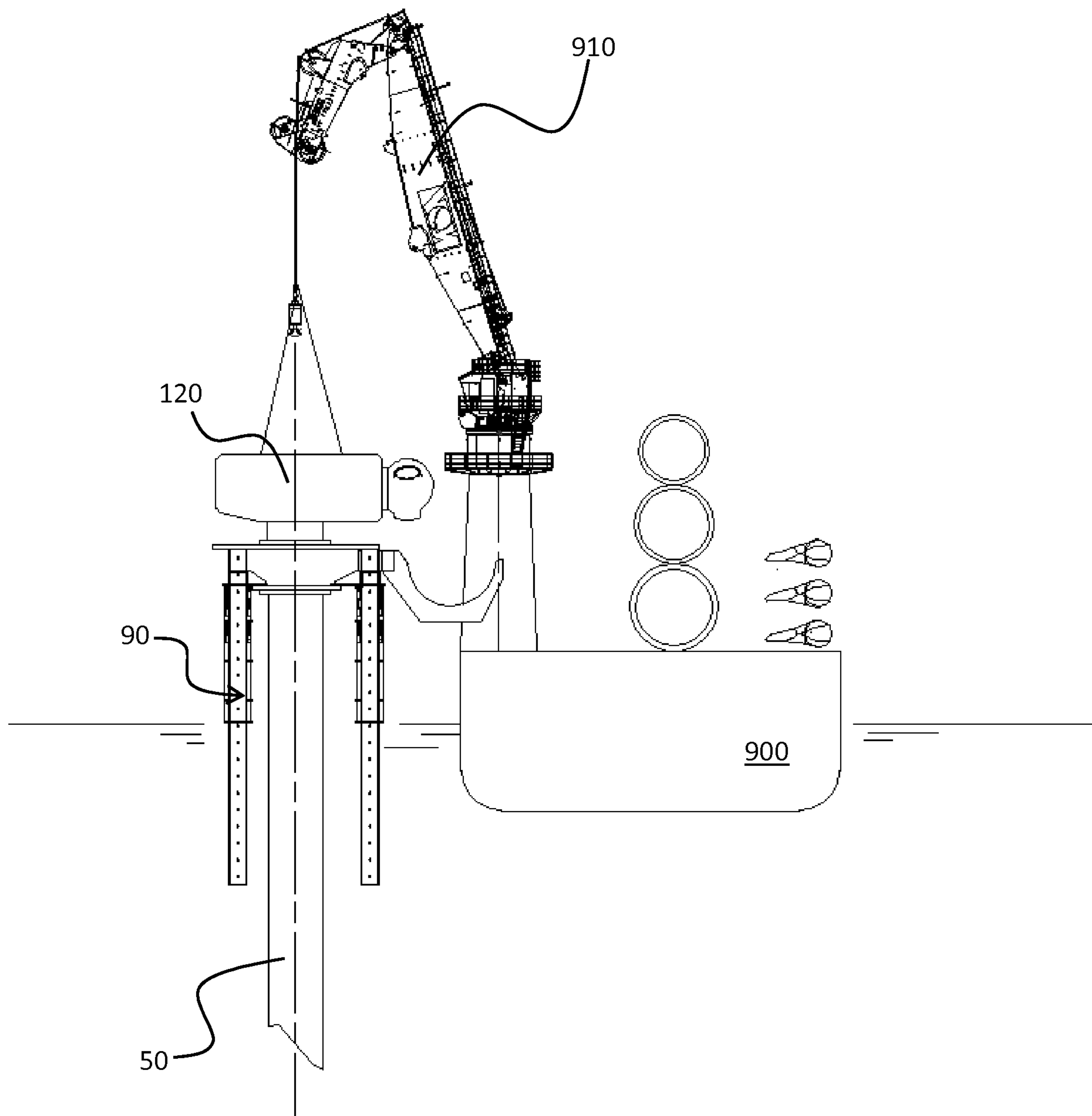


FIG. 3

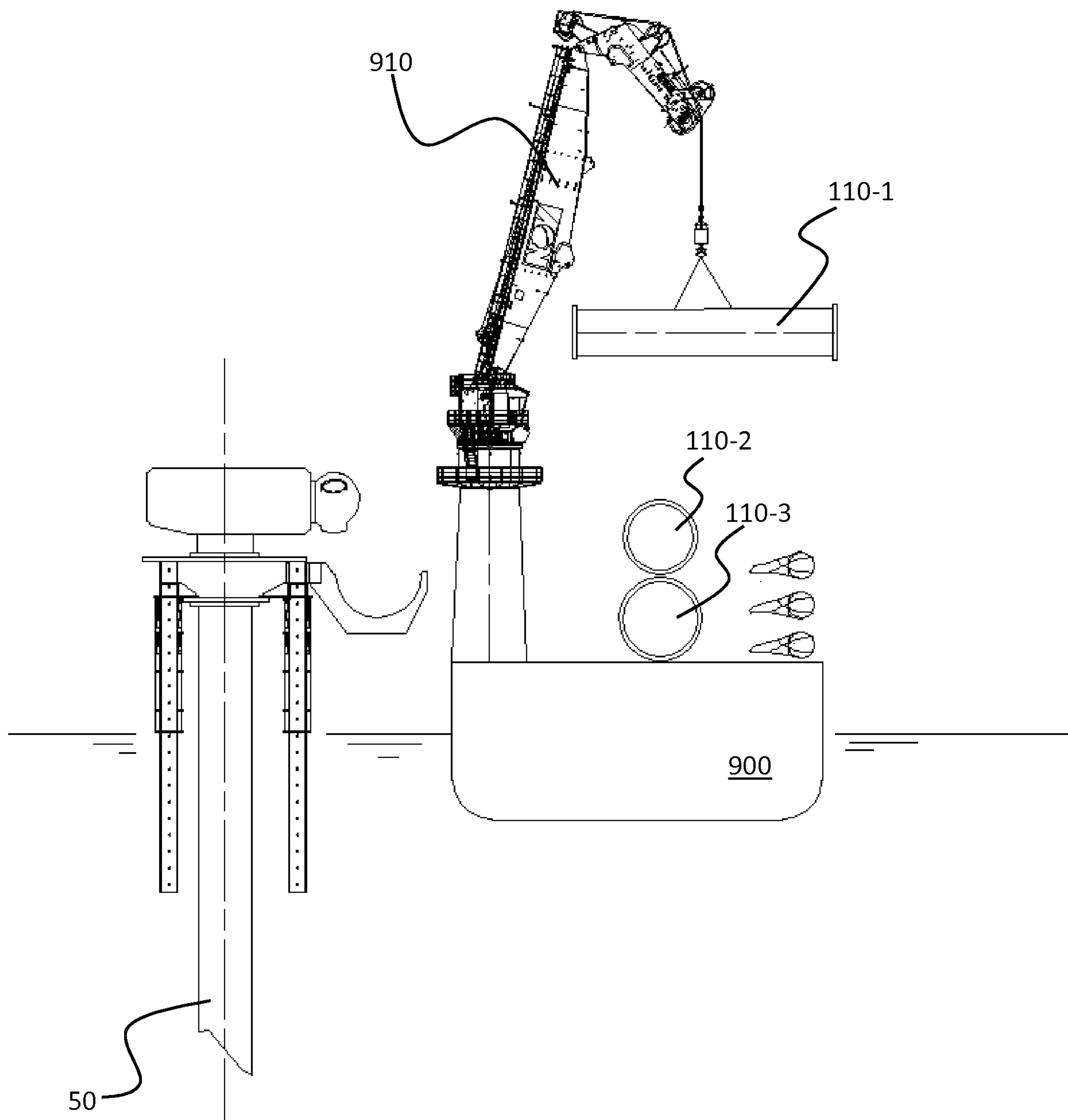


FIG. 4

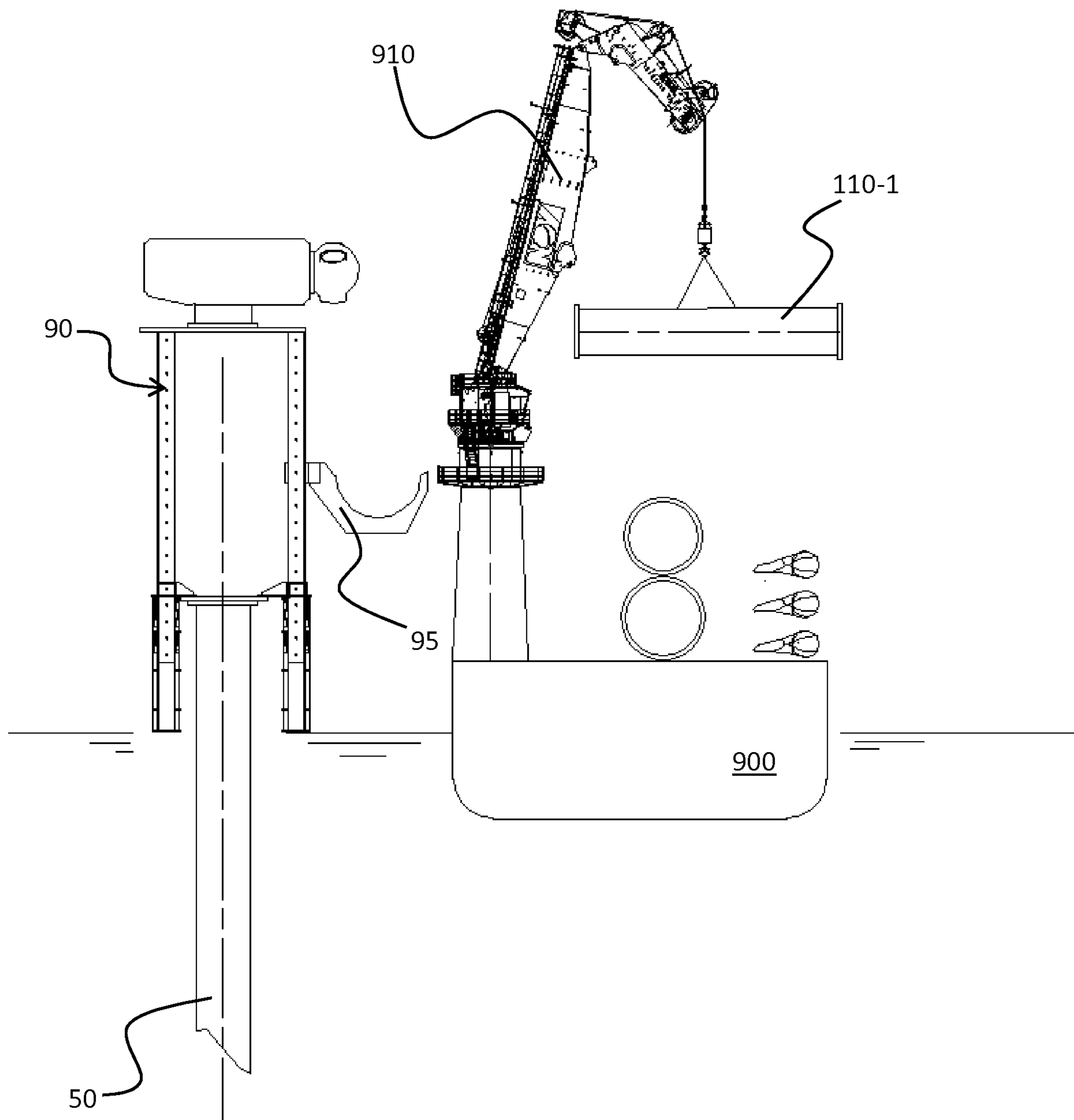


FIG. 5

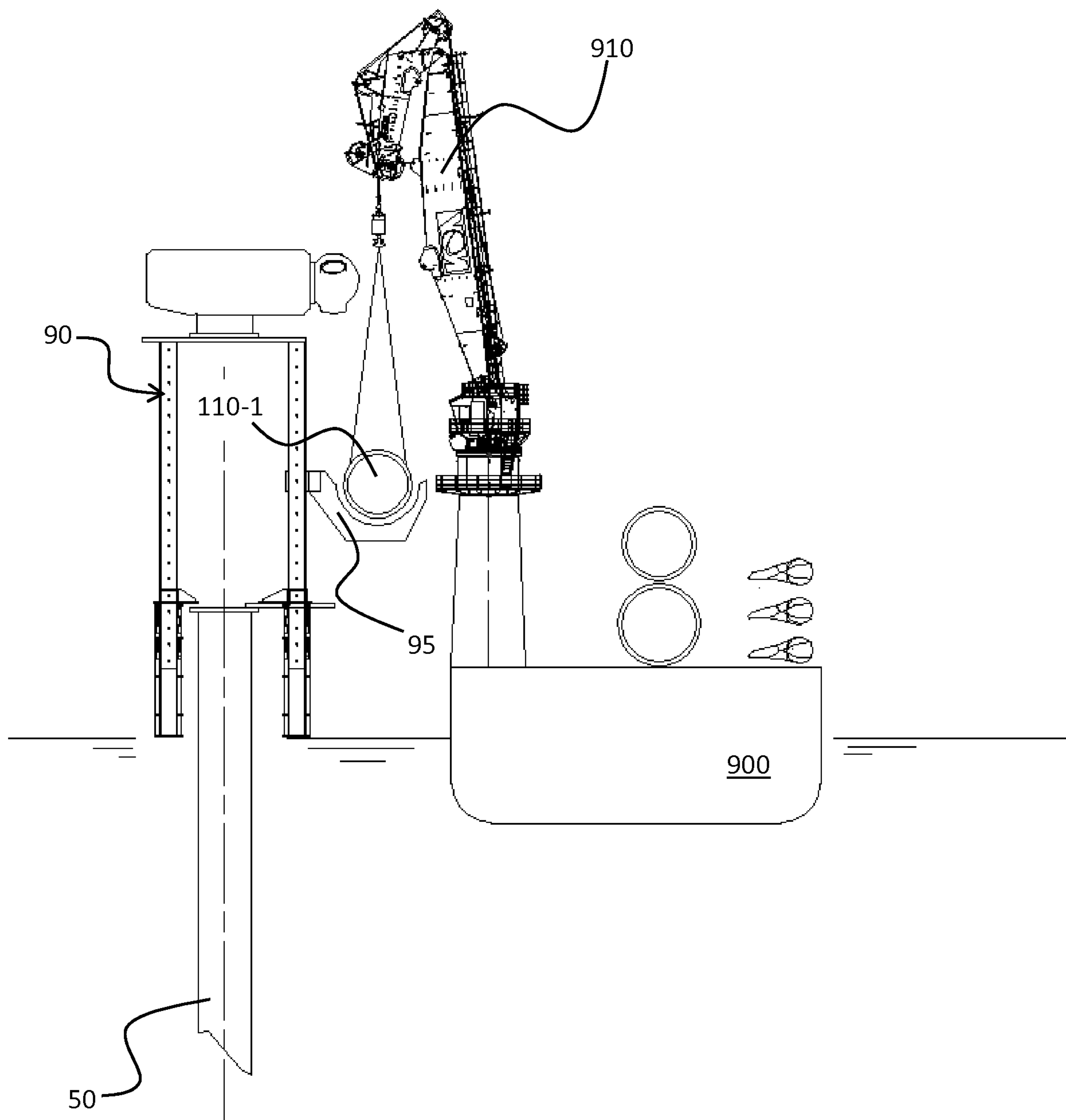


FIG. 6

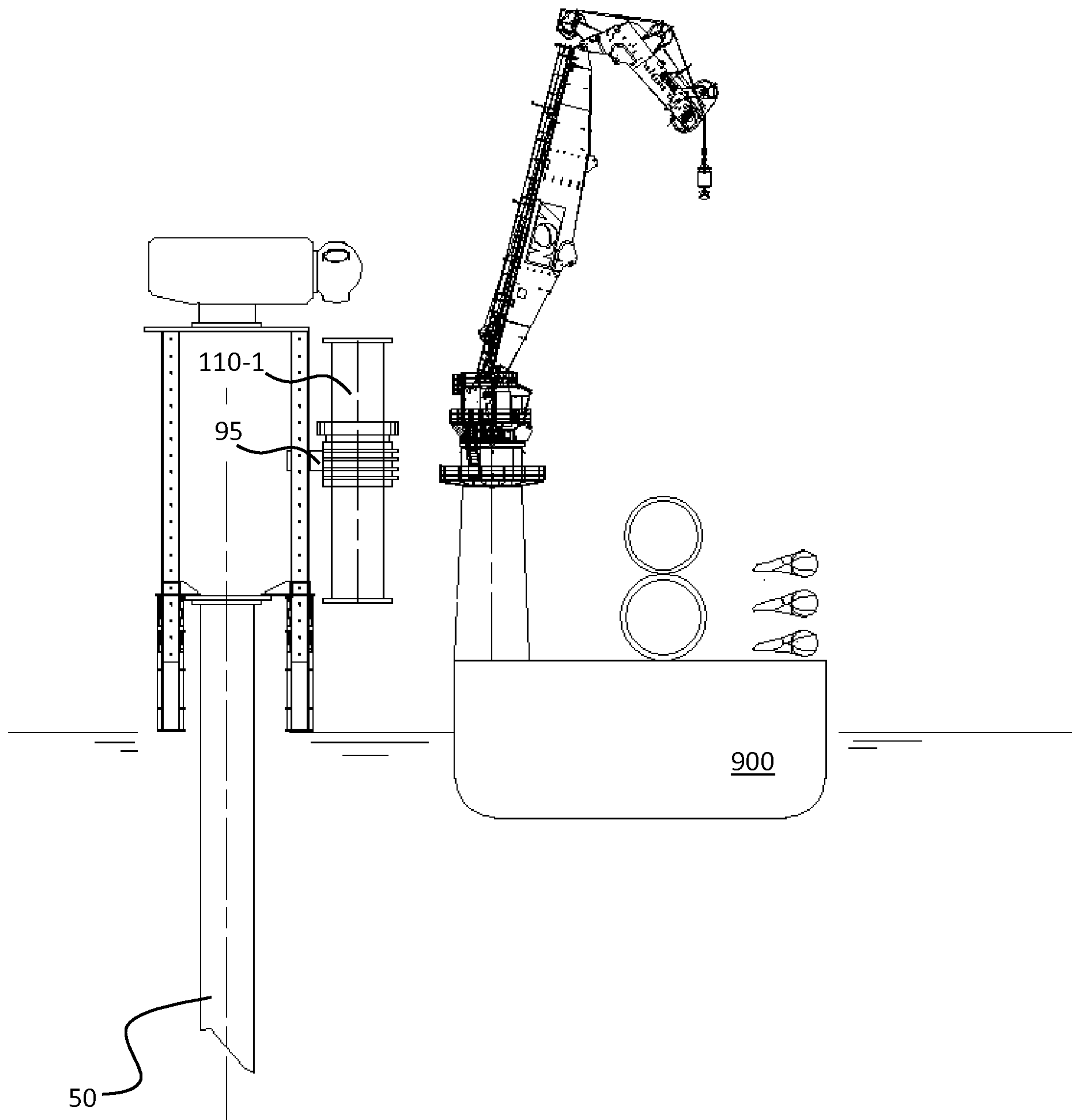


FIG. 7

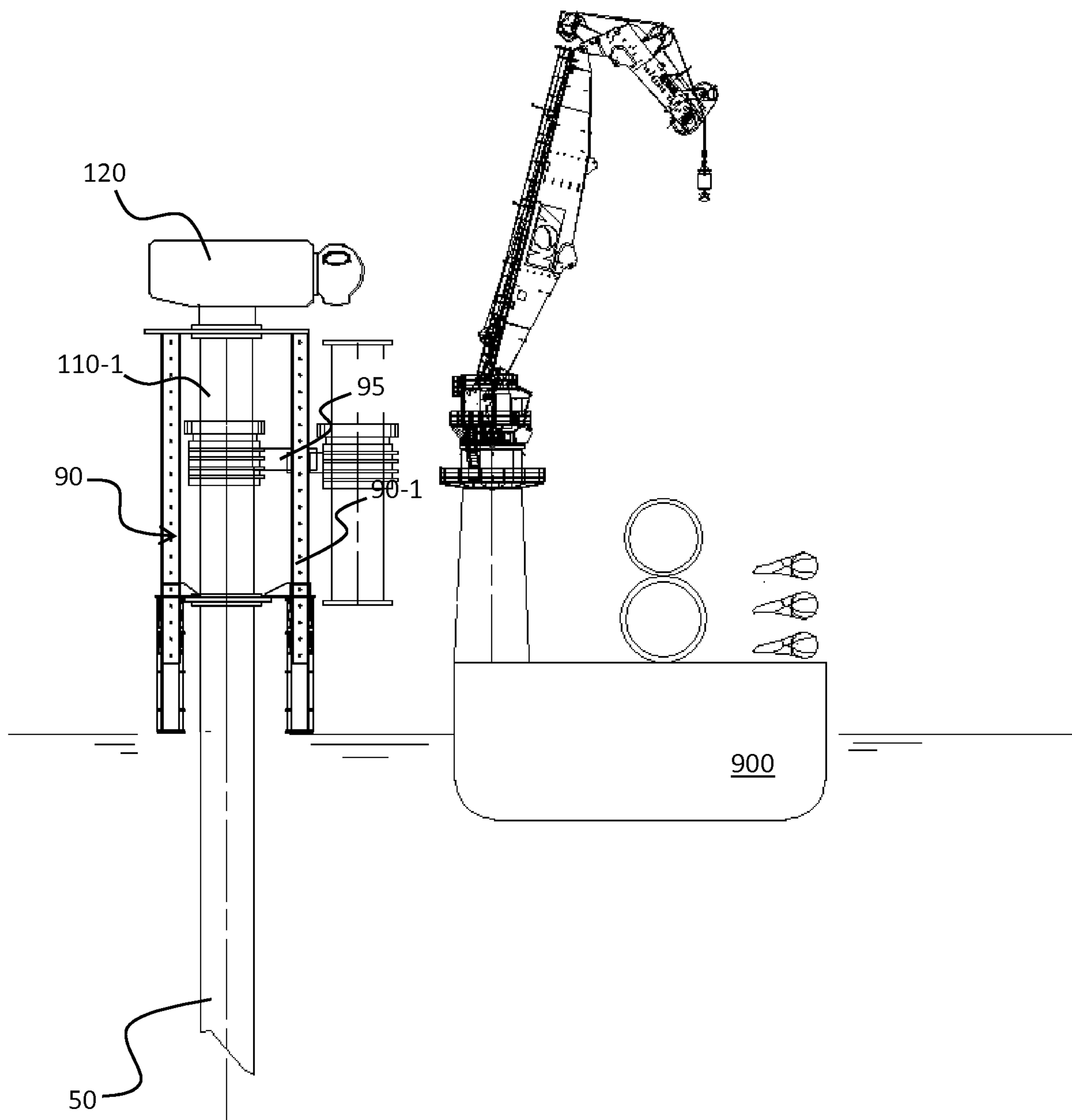


FIG. 8

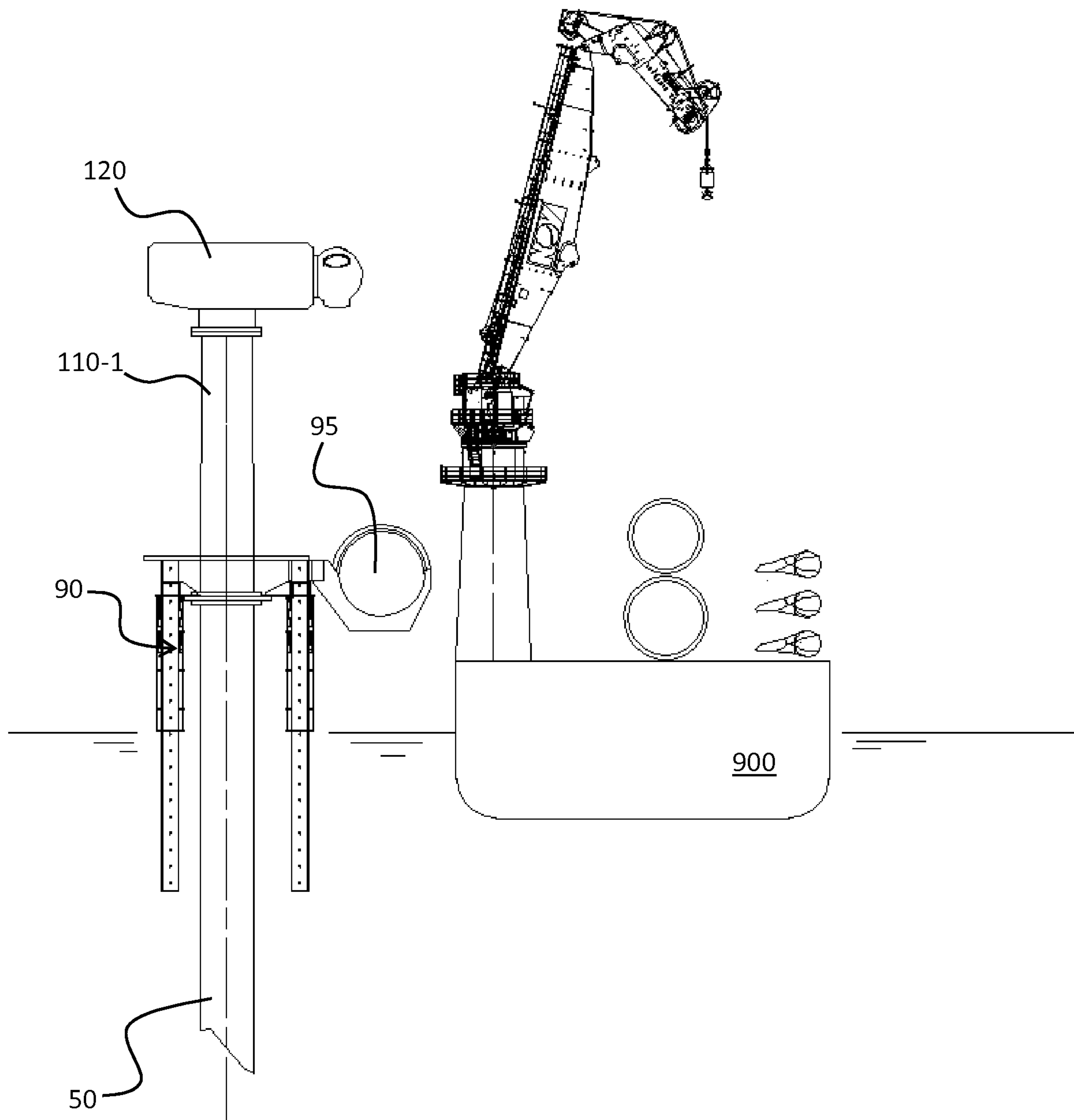


FIG. 9

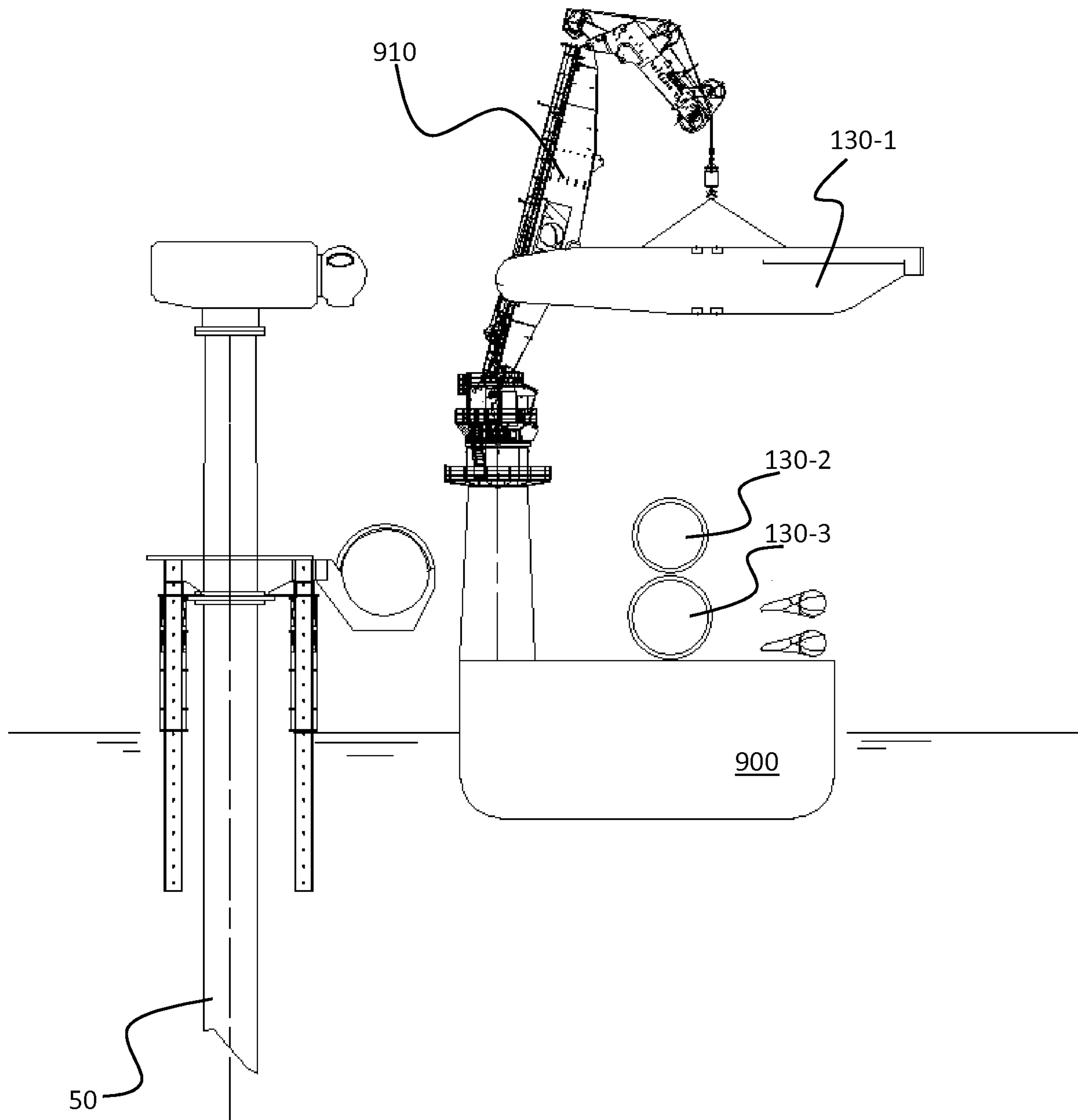


FIG. 10

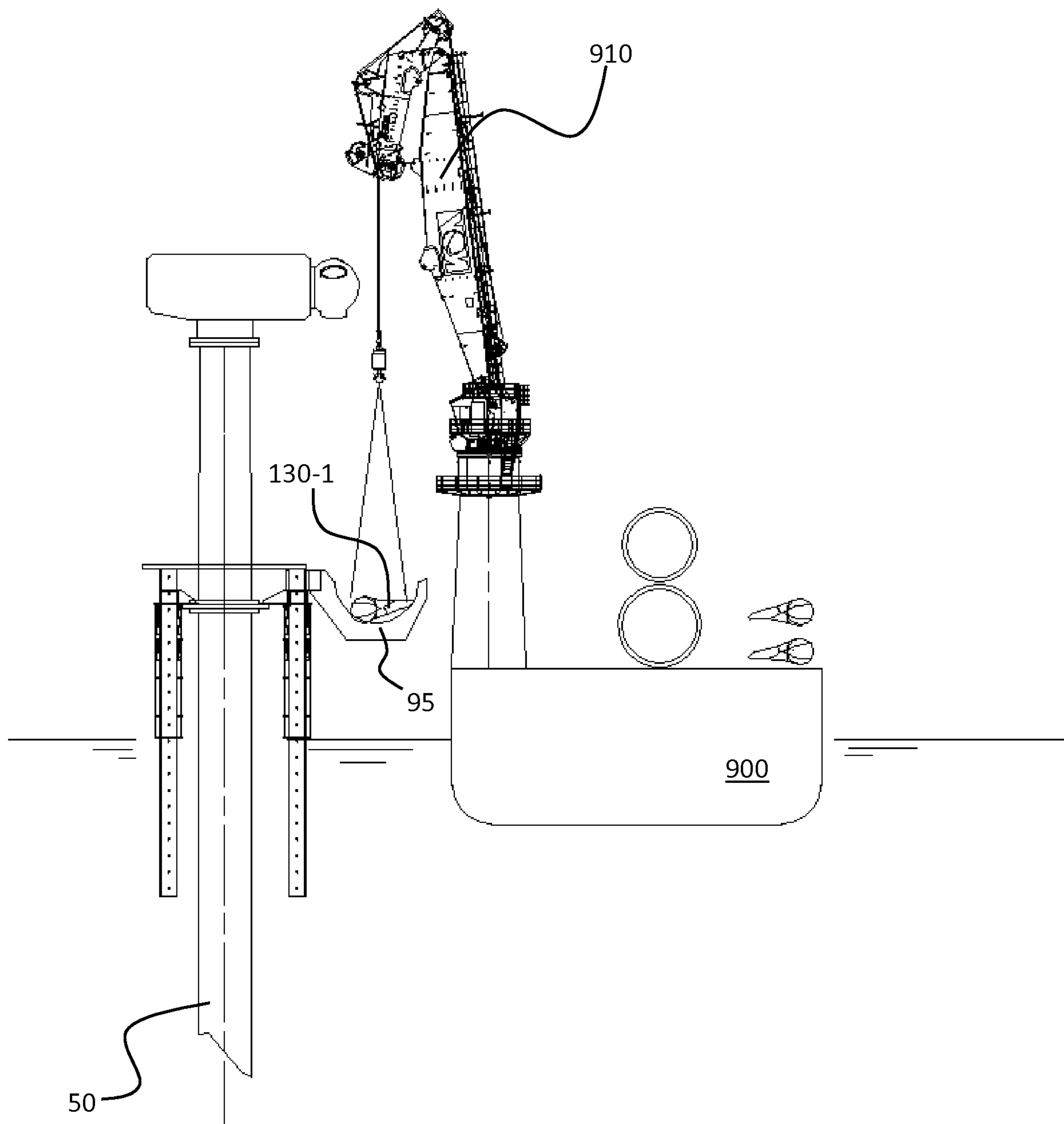


FIG. 11

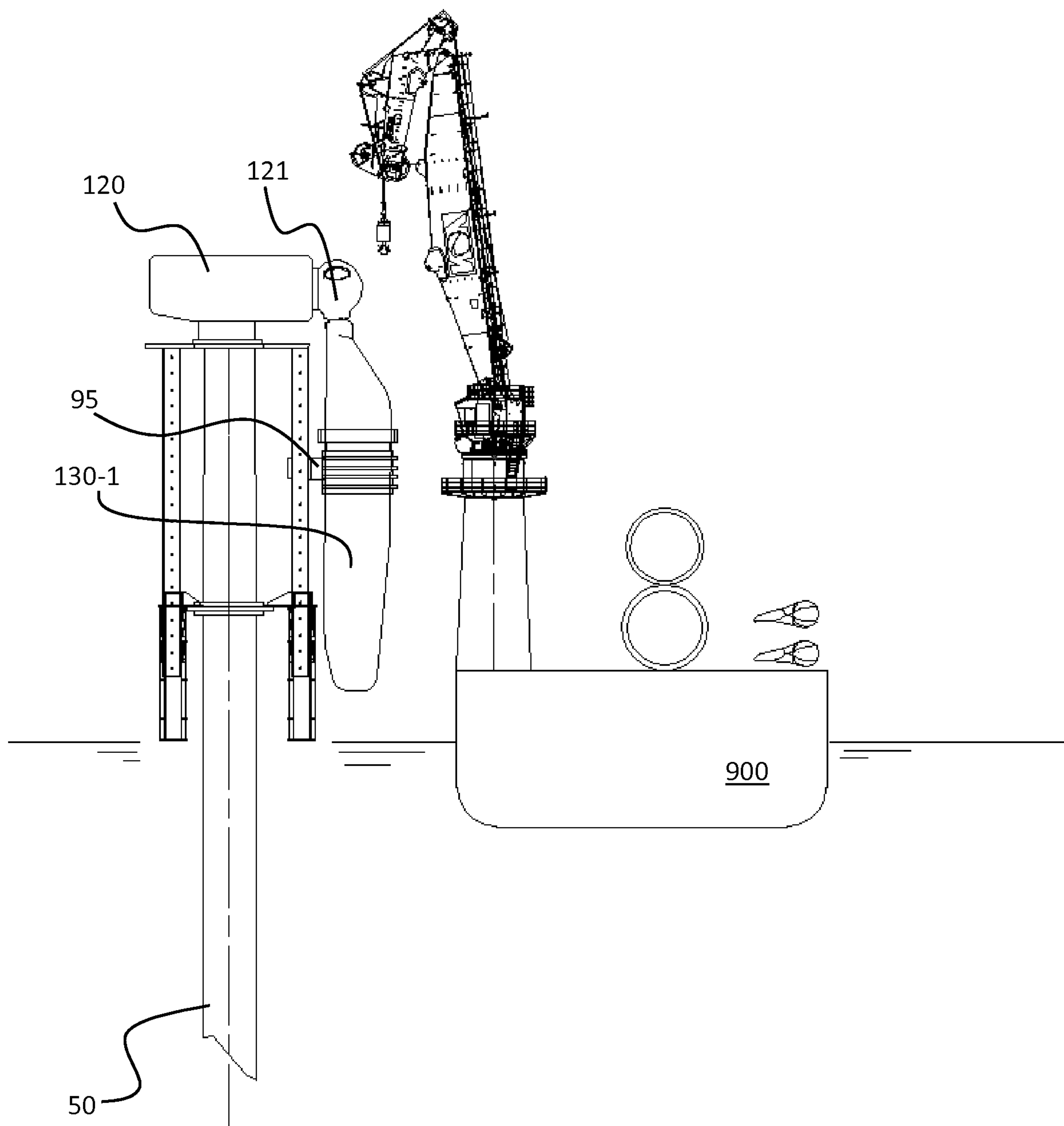


FIG. 12

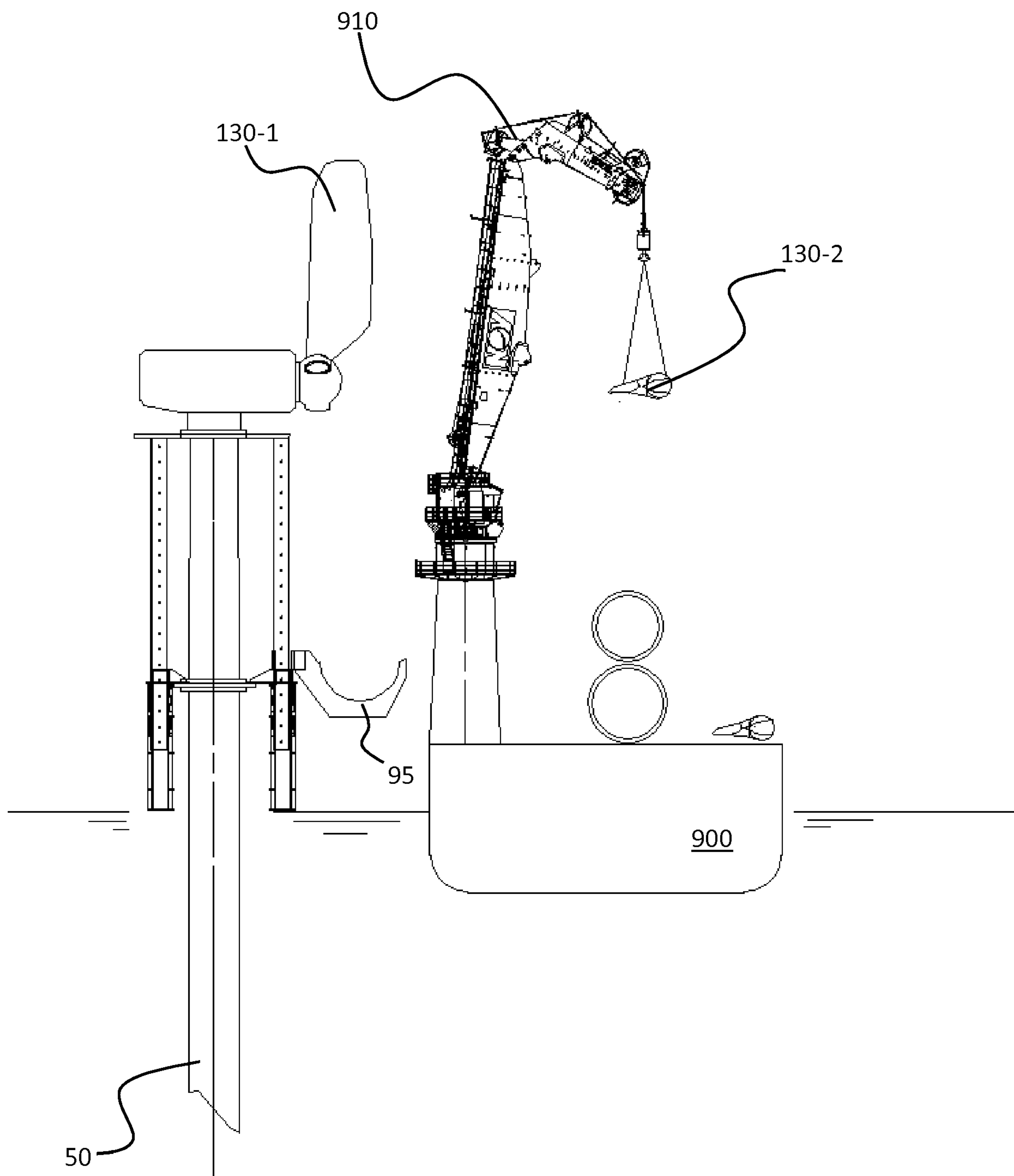


FIG. 13

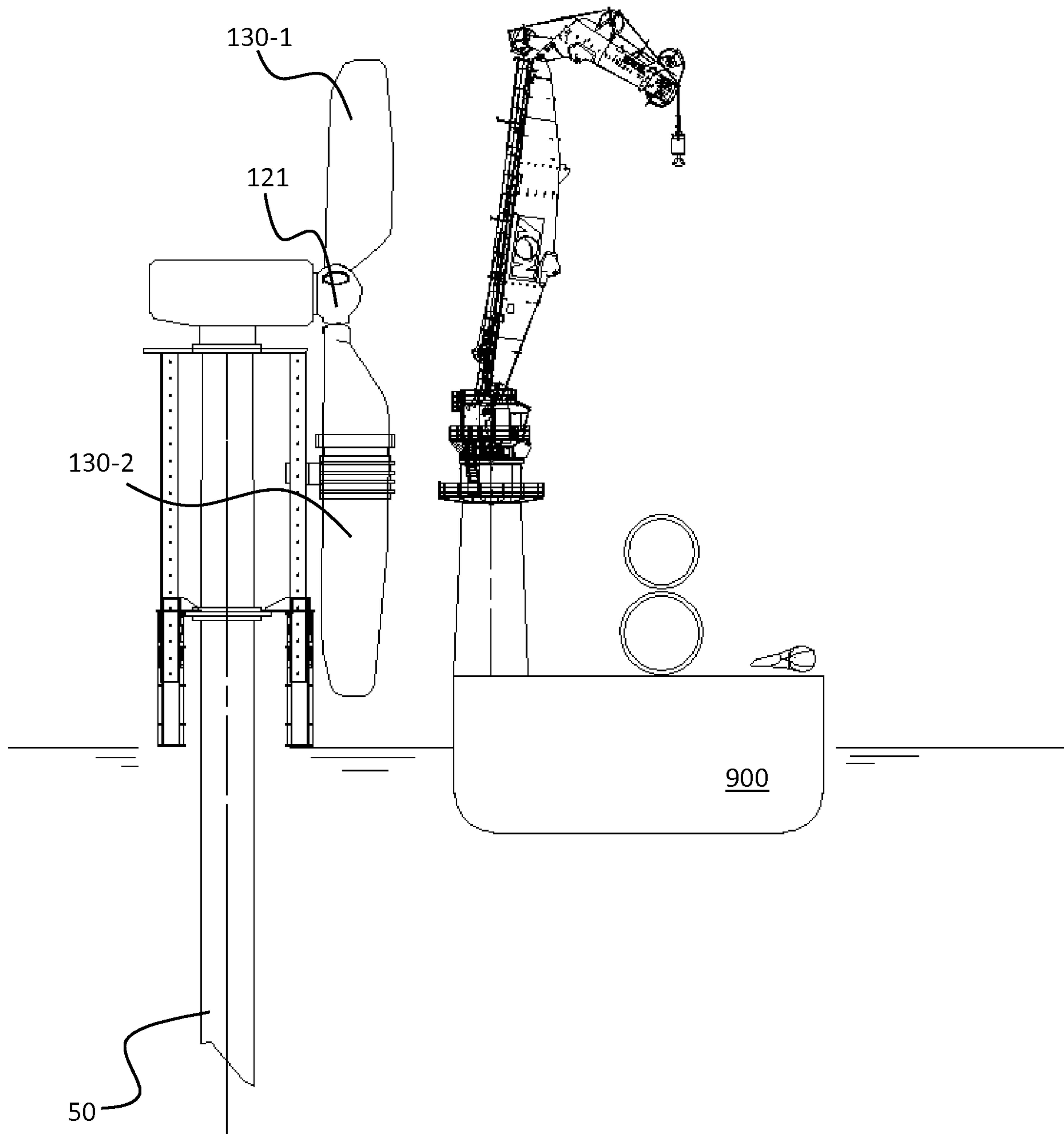


FIG. 14

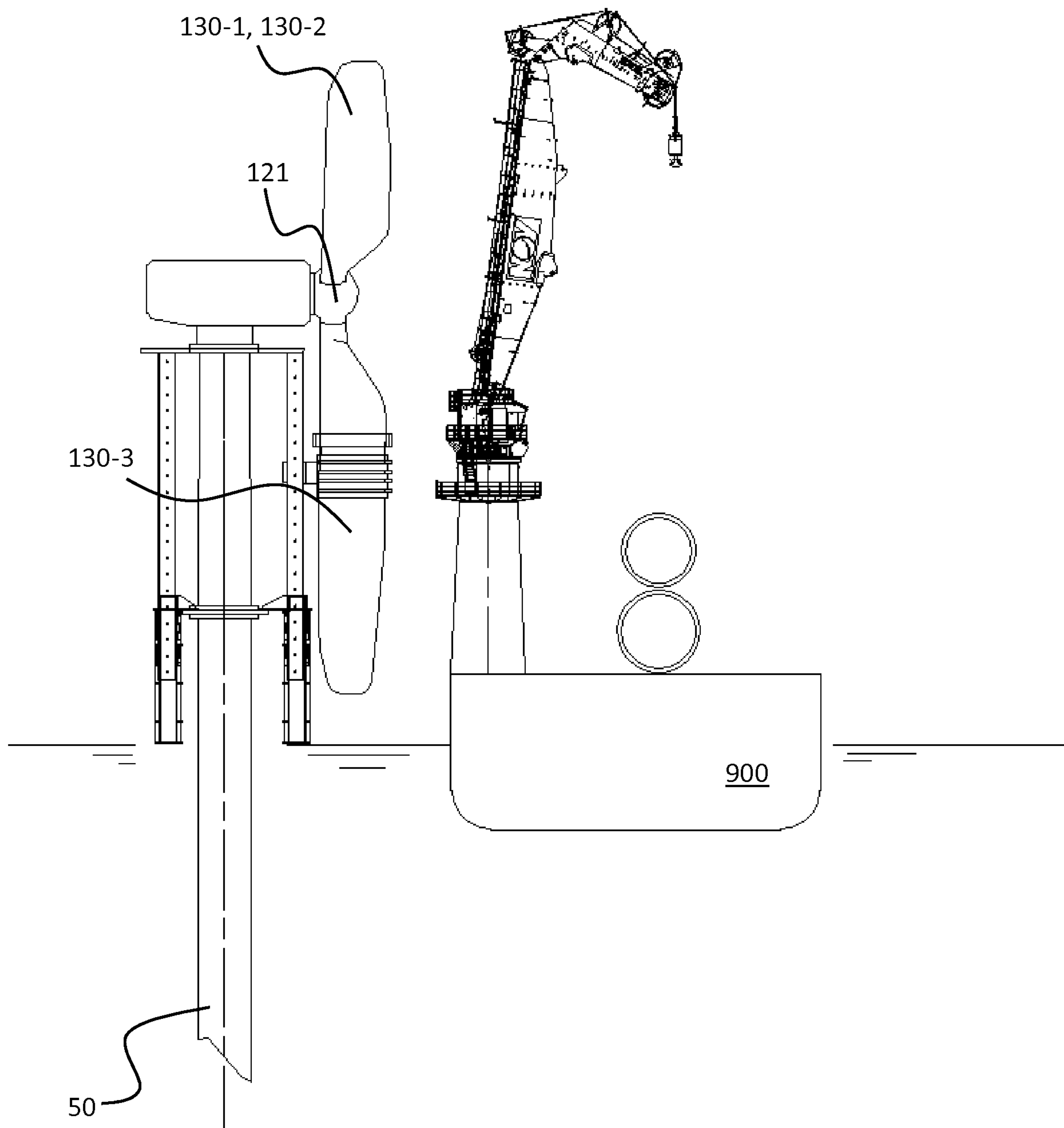


FIG. 15

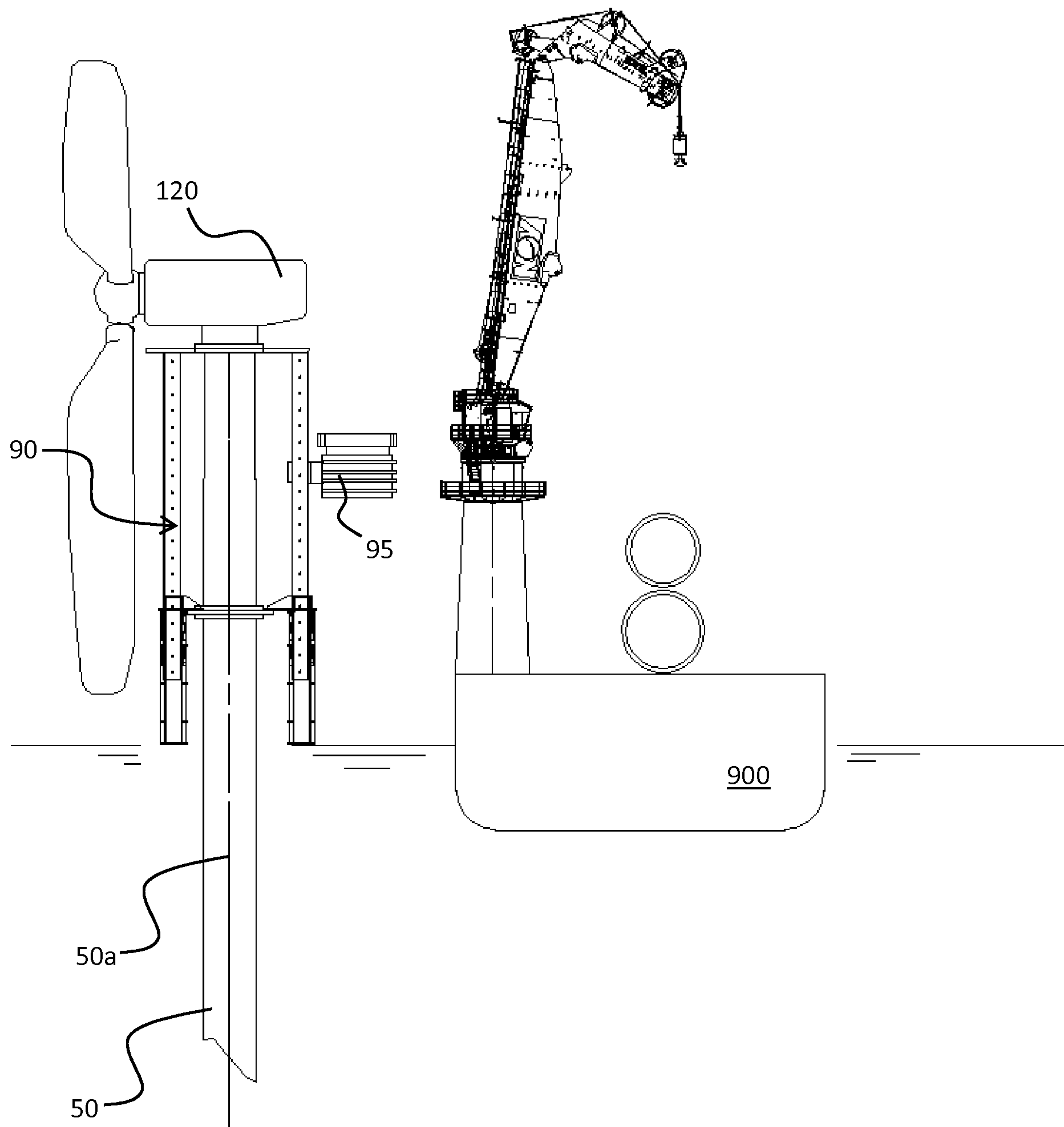


FIG. 16

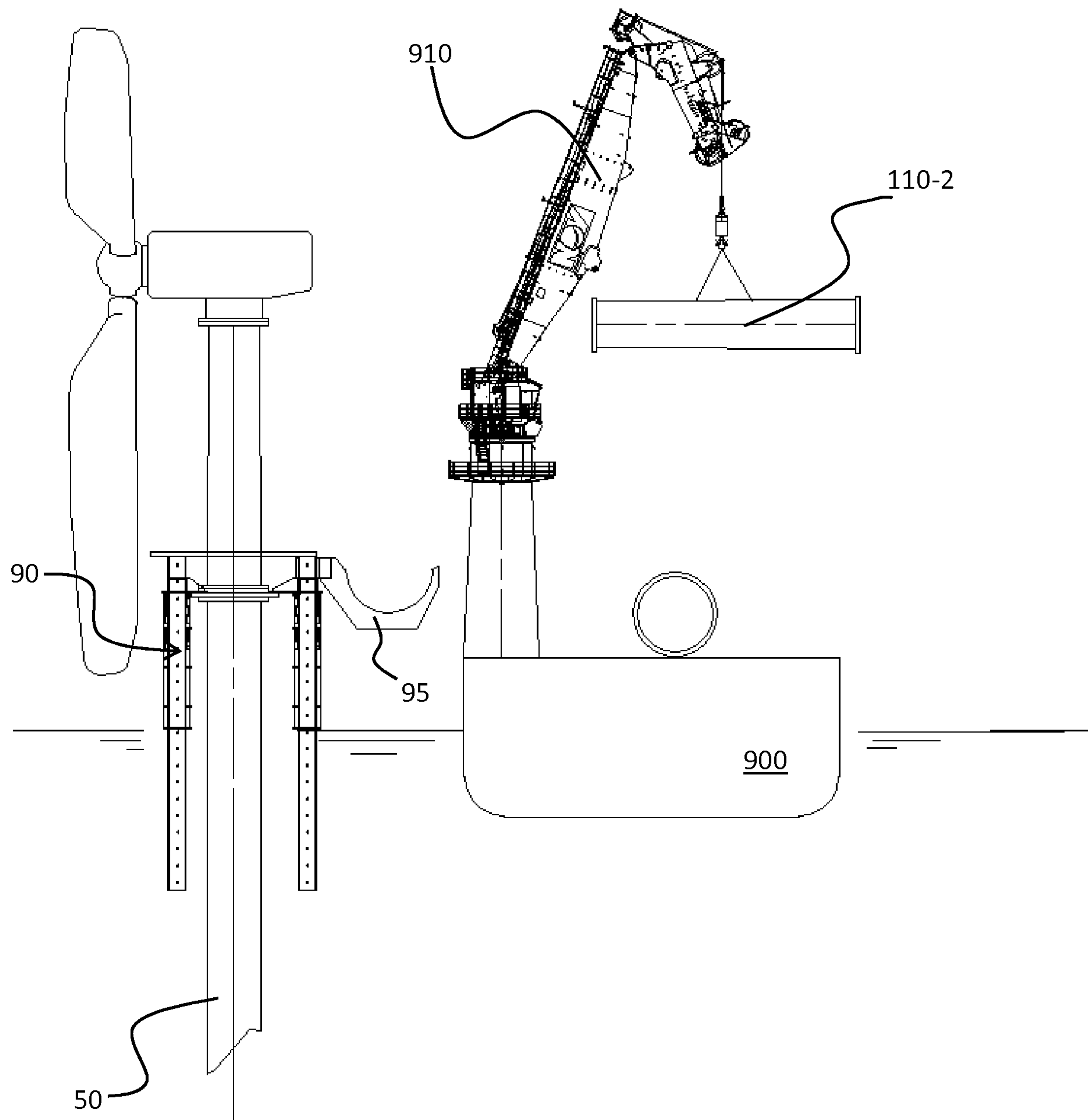


FIG. 17

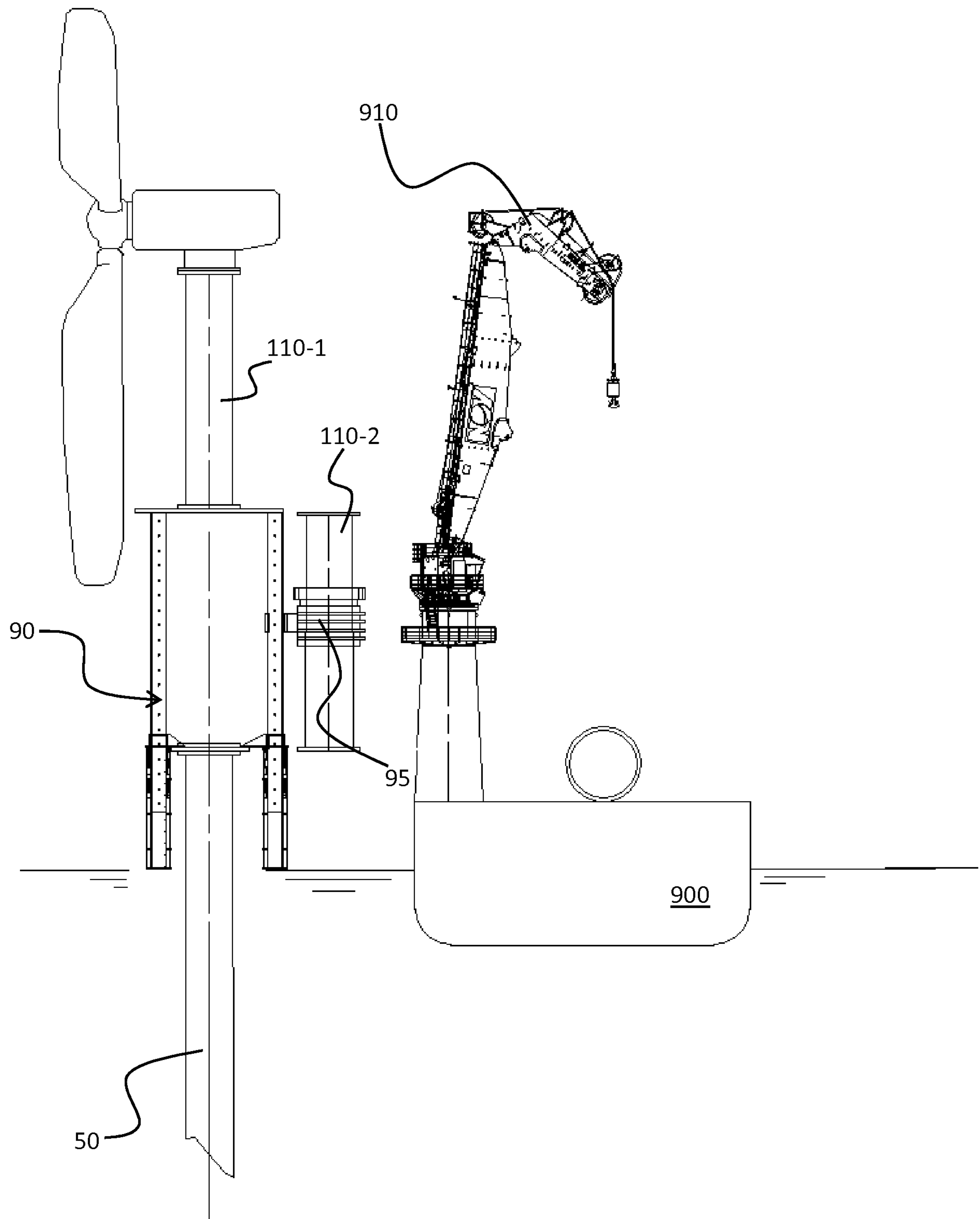


FIG. 18

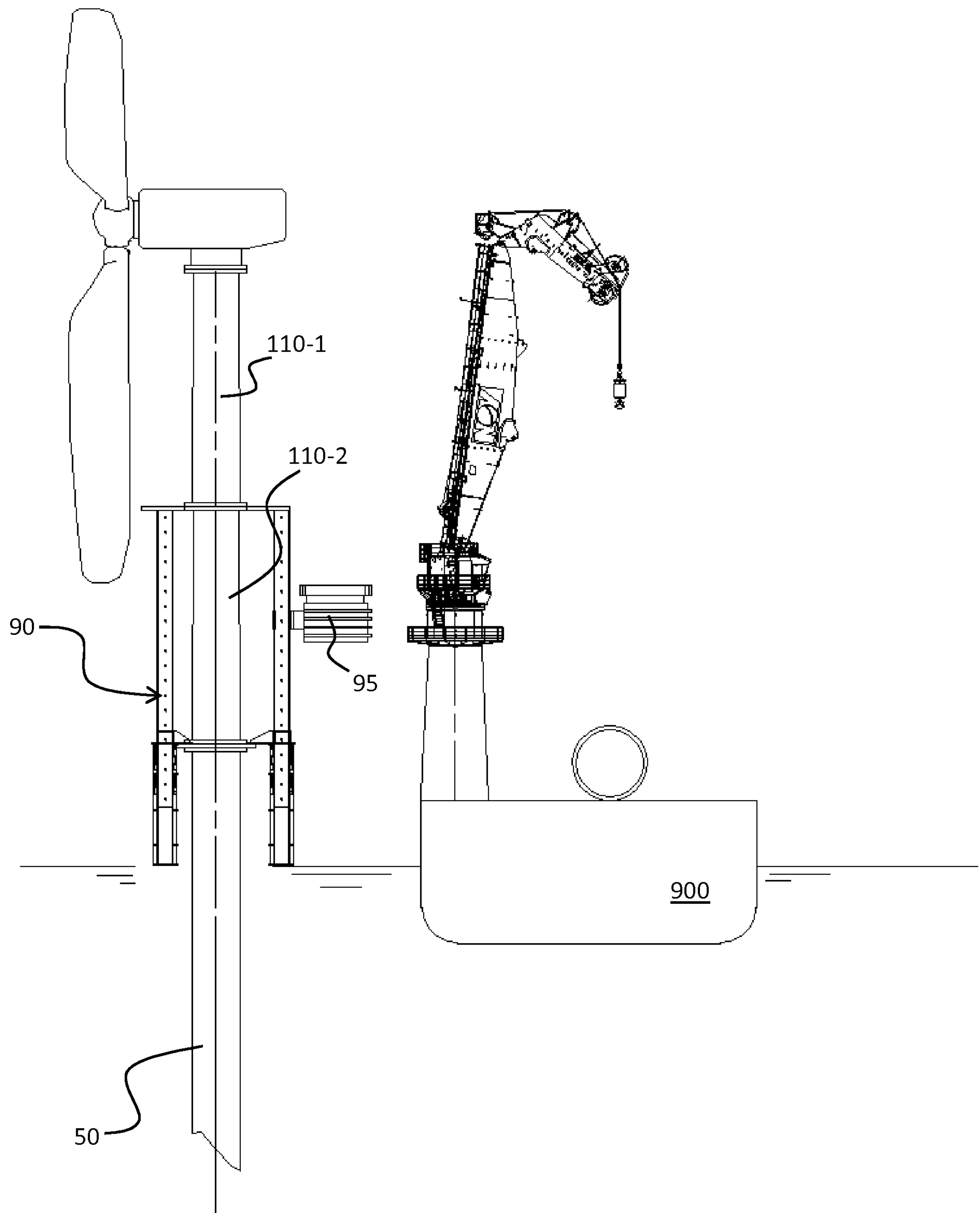


FIG. 19

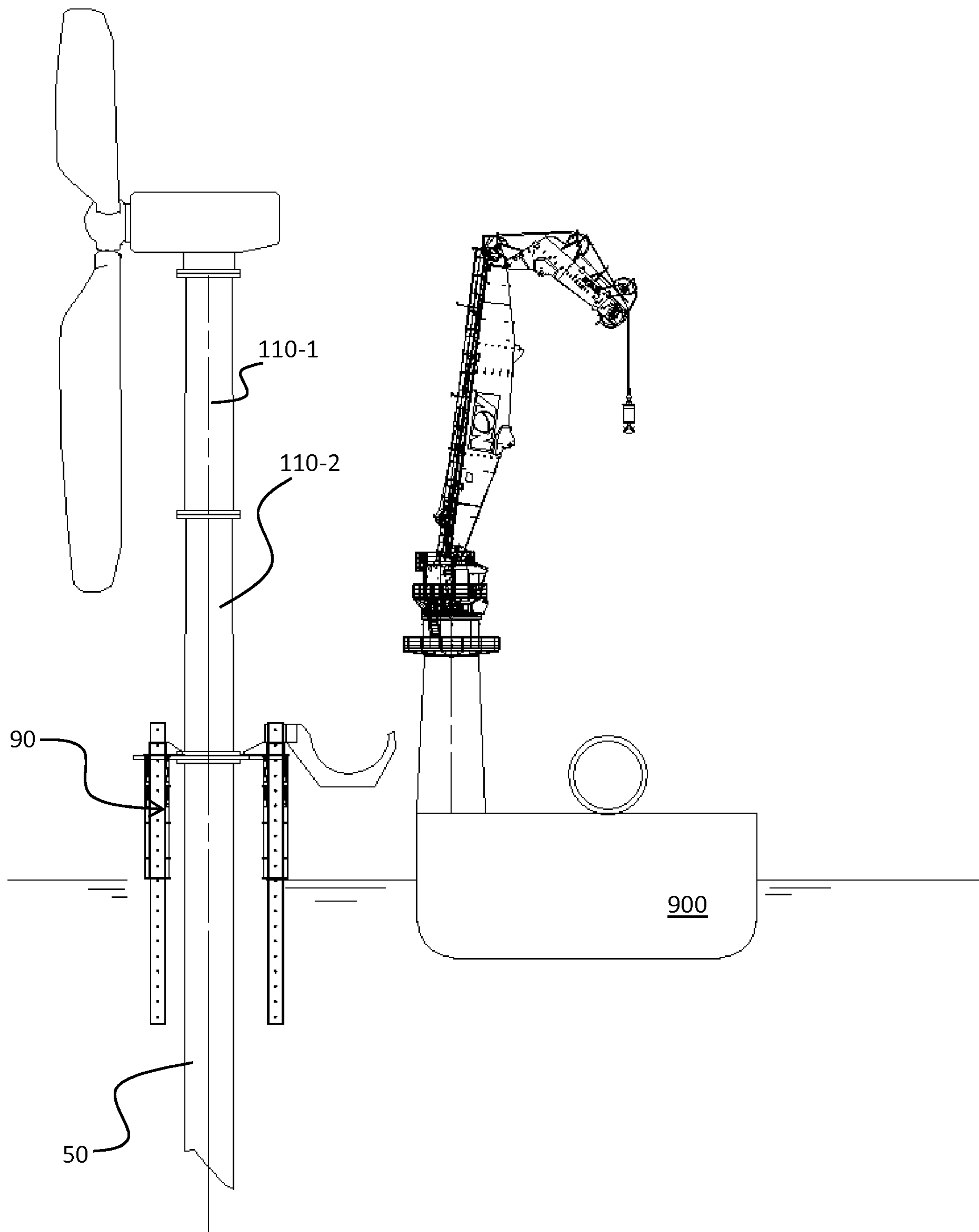


FIG. 20

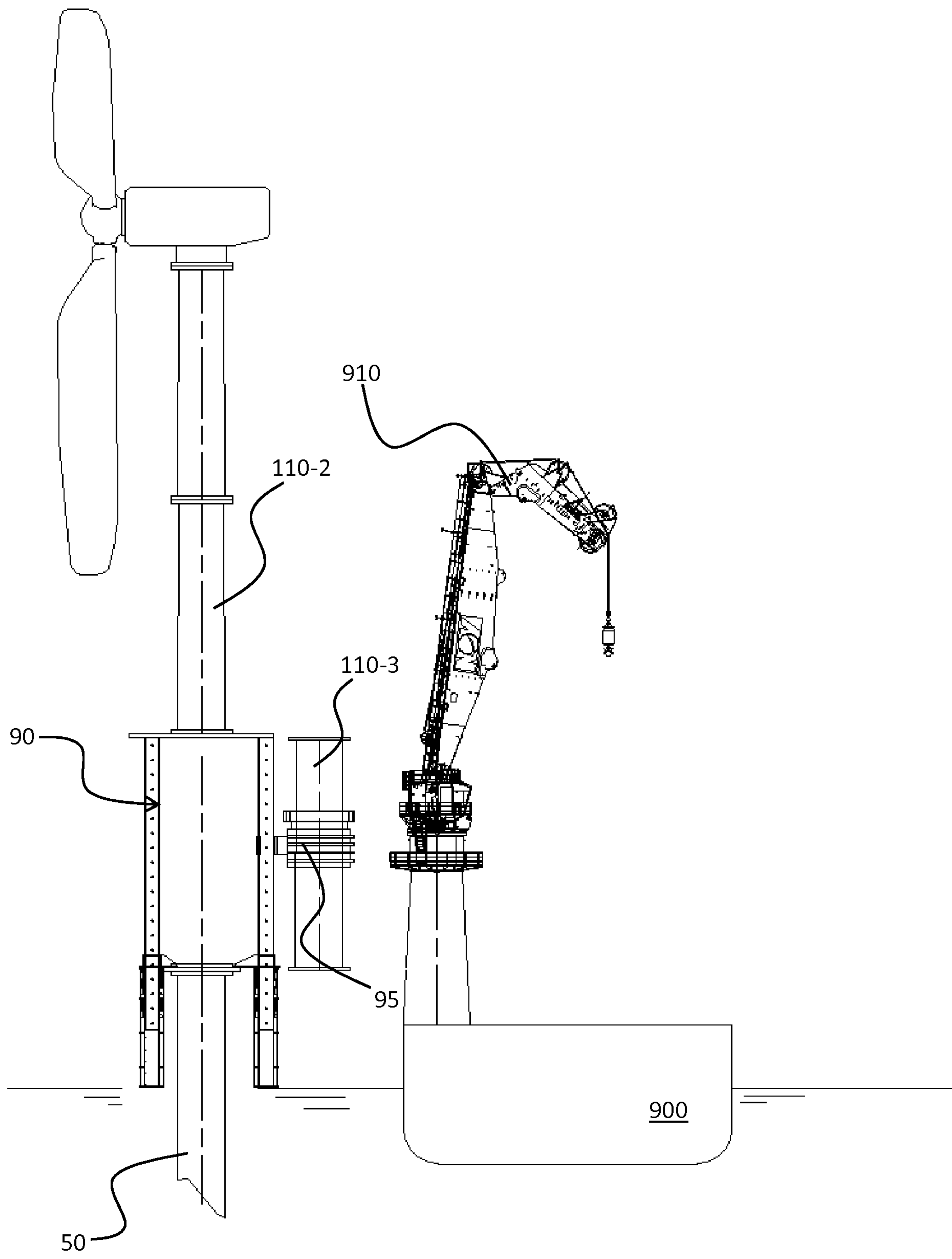


FIG. 21

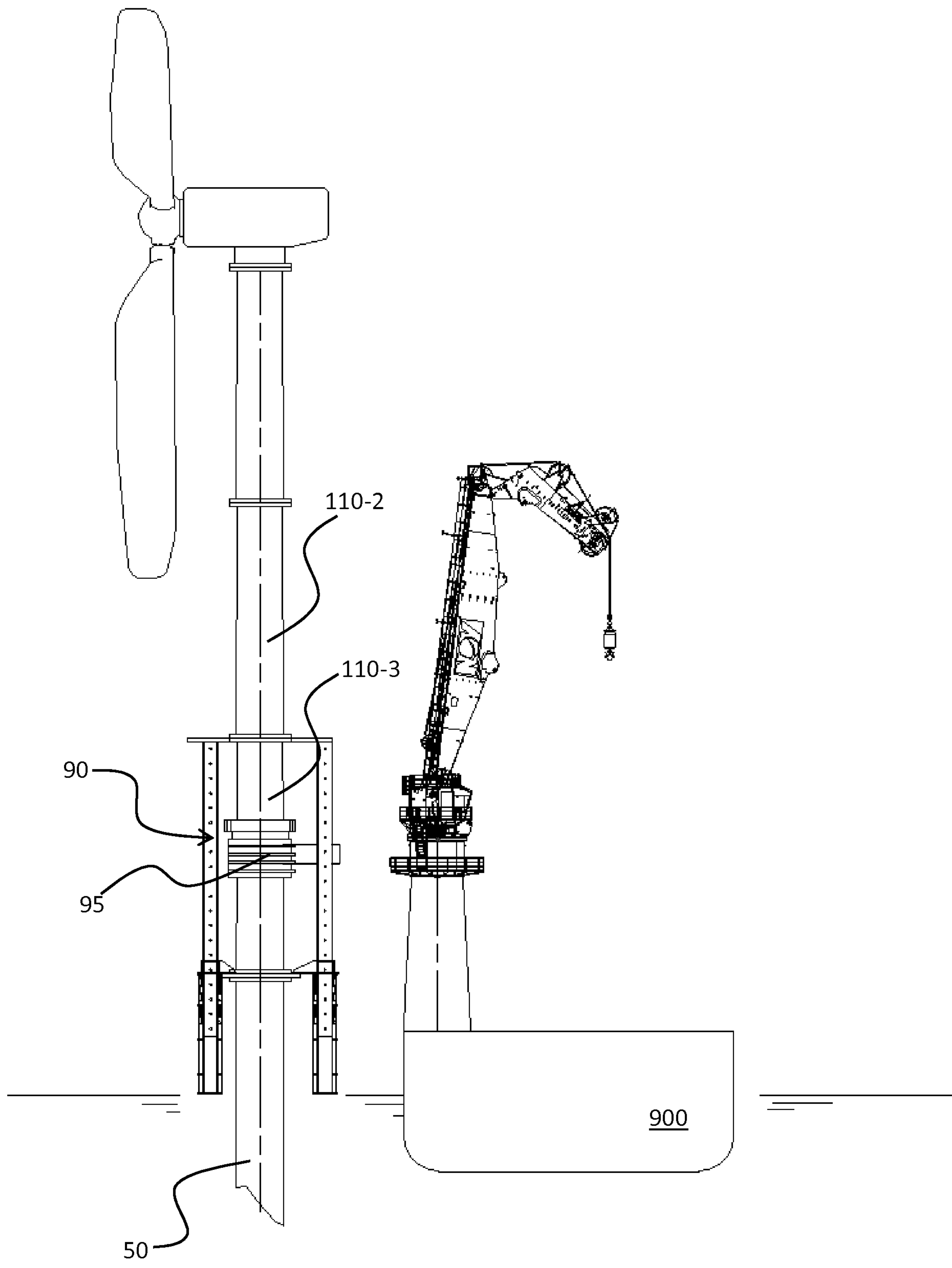


FIG. 22

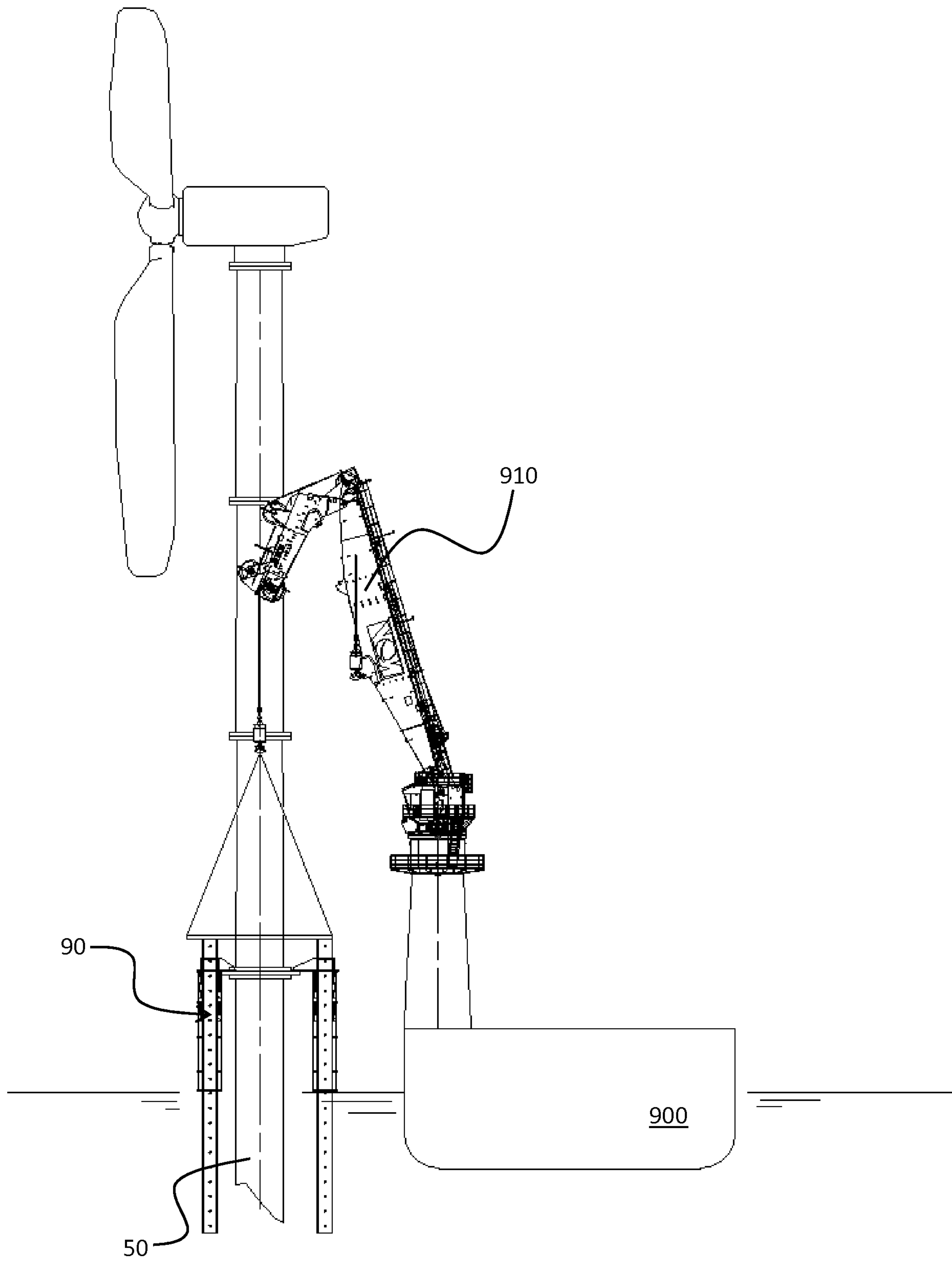


FIG. 23

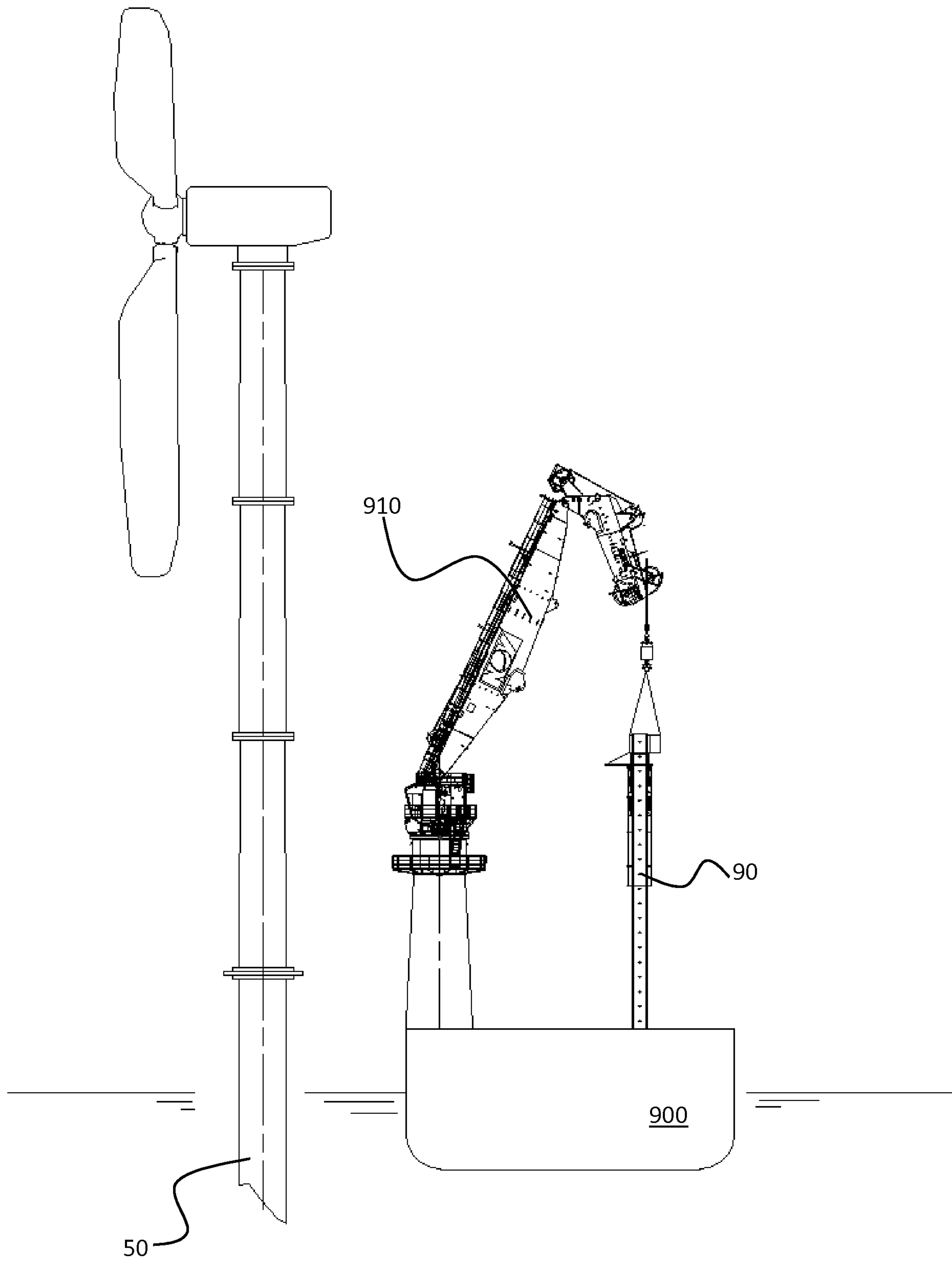


FIG. 24

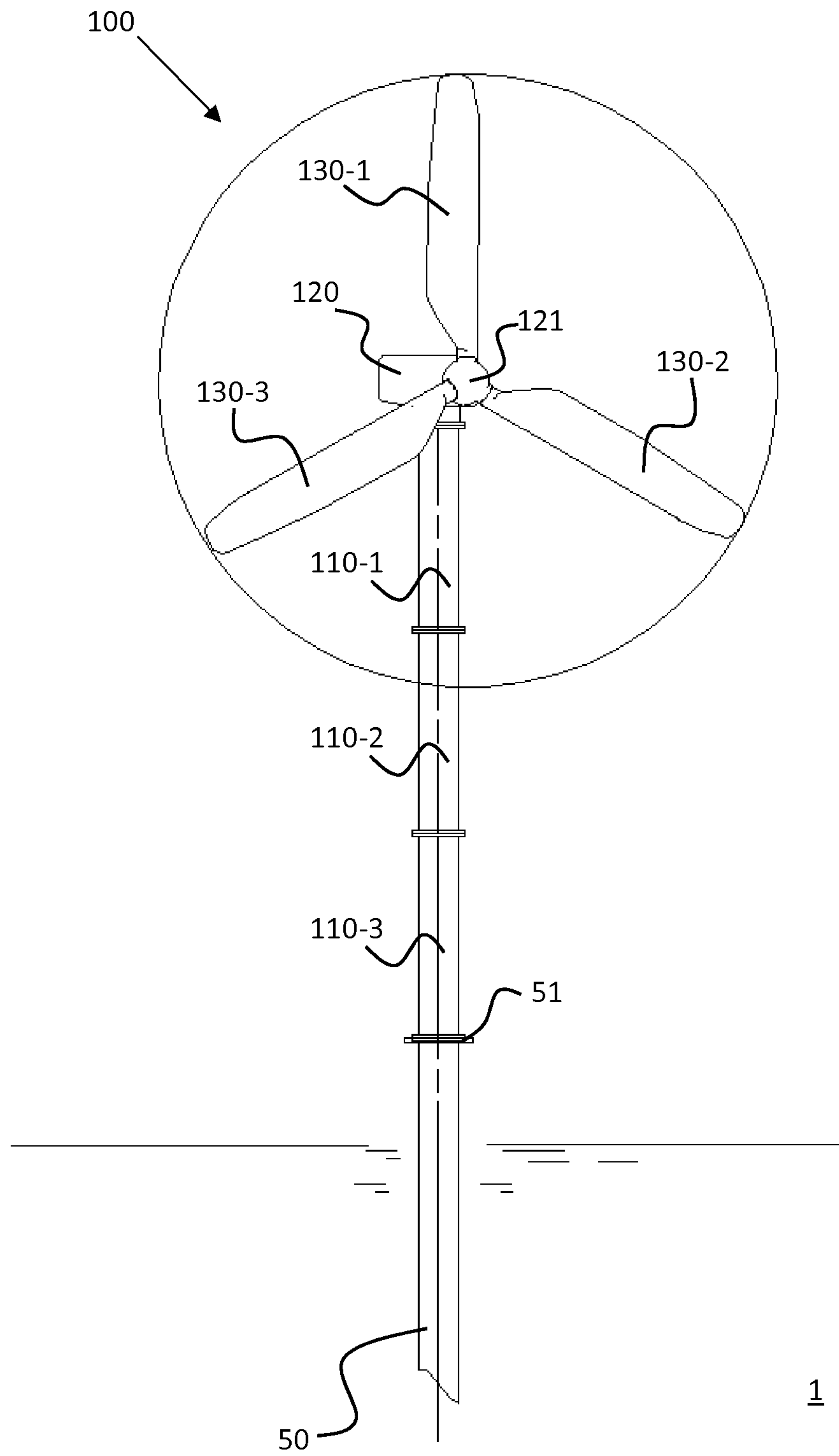


FIG. 25

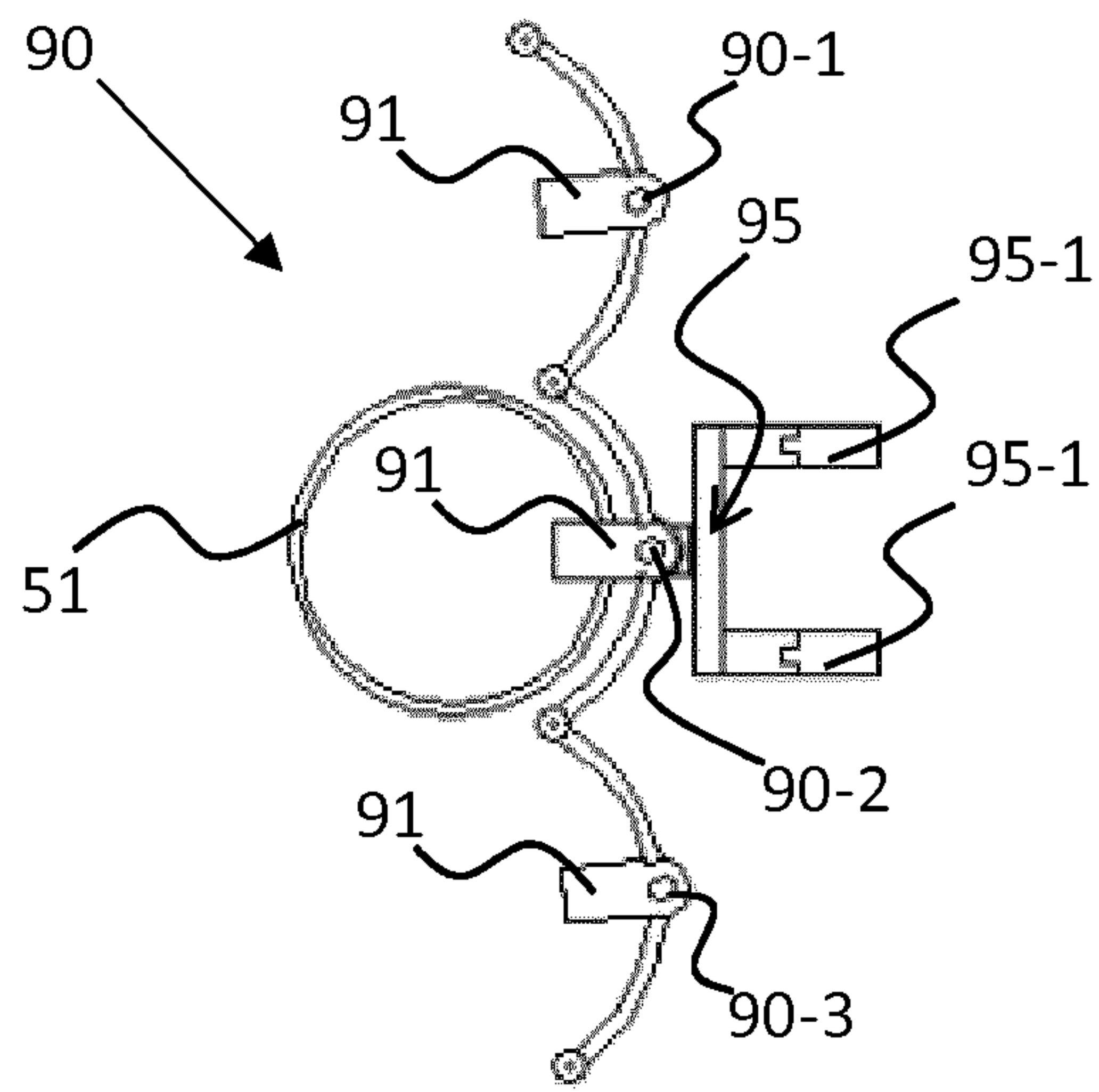


FIG. 26a

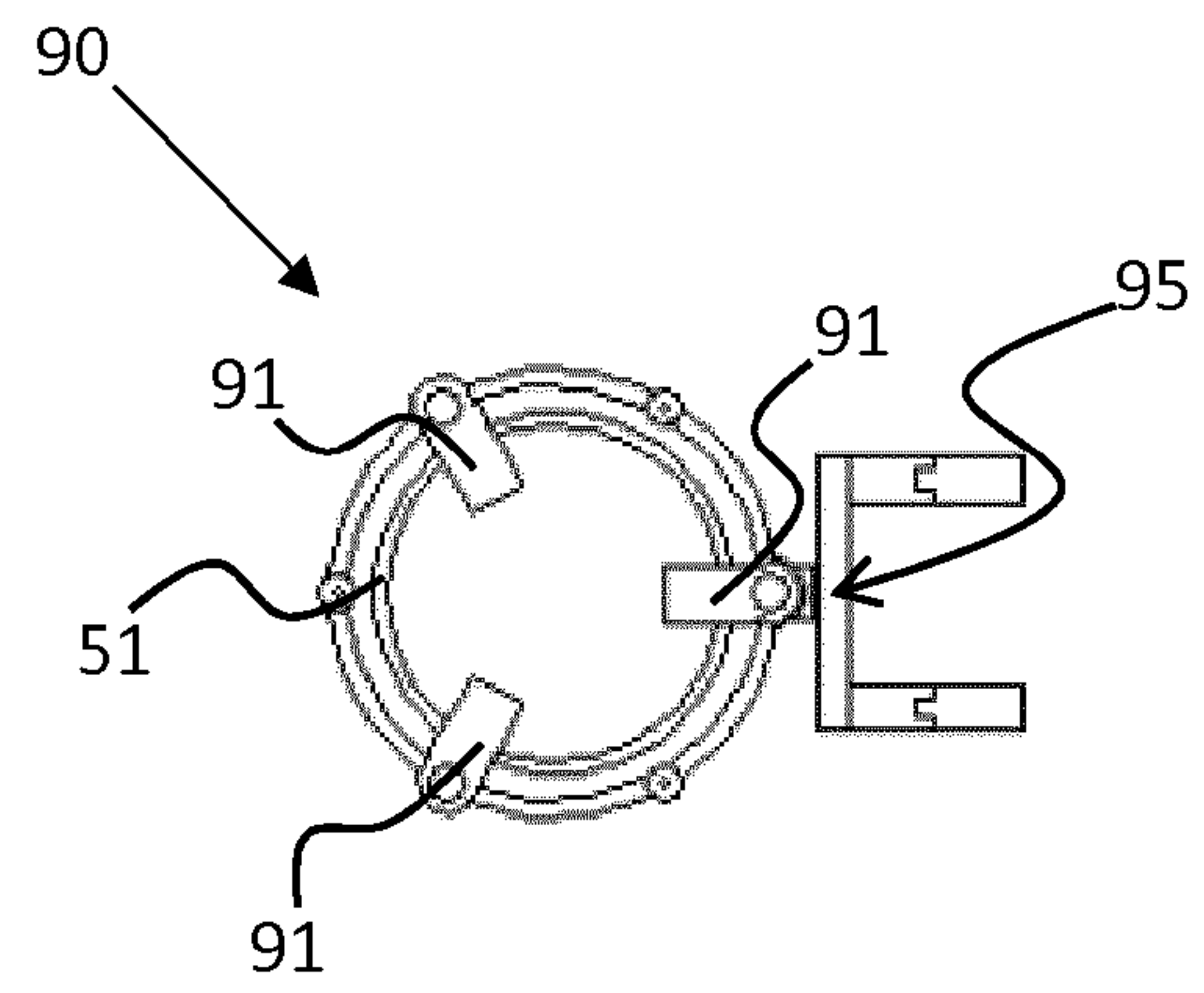


FIG. 26b

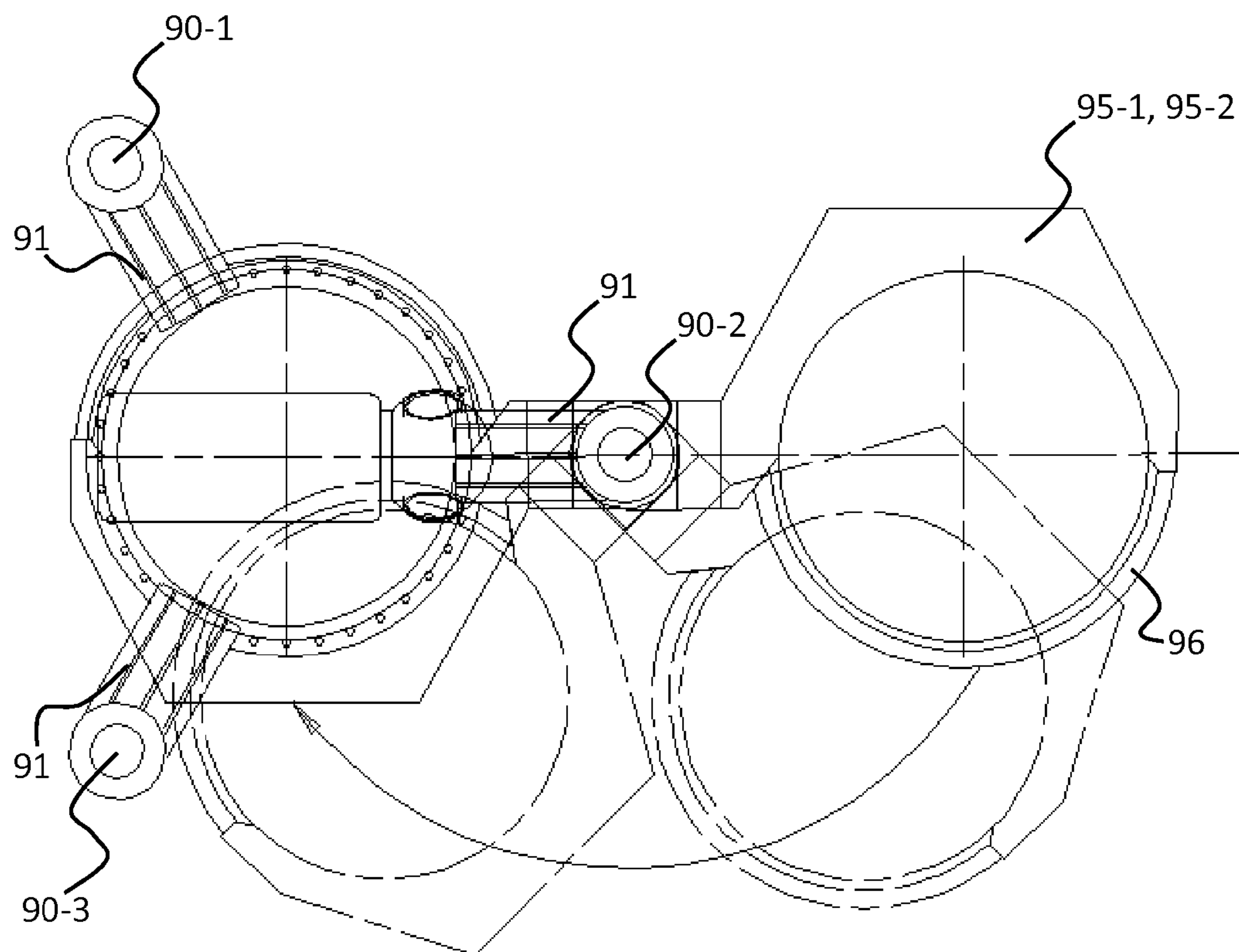


FIG. 27