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

(11) **EP 3 251 943 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
06.12.2017 Bulletin 2017/49

(51) Int Cl.:
B63B 21/50 *(2006.01)*

(21) Application number: **17174598.7**

(22) Date of filing: **06.06.2017**

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

(30) Priority: **03.06.2016 NO 20160964**
26.10.2016 US 201615335191

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(54) **MOORING PULLEY TENSIONING SYSTEM**

(57) The invention relates to a mooring tensioning arrangement for a floating structure or vessel, wherein the mooring tensioning arrangement comprising, an anchor (2), a mooring line (3, 7), a fairlead chain stopper arrangement (12) arranged on the floating vessel (11), a midwater pulley device (4, 4', 4") and a pulling unit (9, 10, 42, 51,52), said mooring line (3,7) is attached to the anchor (2) at a first end and attached to the pulling unit (9, 10, 10', 42, 51,52) at the second end, said mooring line (3) is extending from the anchor (2) through the fairlead chain stopper arrangement (12), said midwater pulley (4, 4',4") is adapted to be arranged on a part of the mooring line (3, 7) arranged between the anchor (2) and the fairlead chain stopper arrangement (12), said fairlead chain stopper arrangement (12) comprising a chain stopper (6) interacting with said mooring line (3, 7) and a chain pulley (8) guiding the mooring line (3) through the fairlead chain stopper arrangement (12) and back towards the midwater pulley (4, 4', 4") and from said midwater pulley (4, 4', 4") towards said pulling unit (9, 10, 10', 42, 51, 52). The invention also relates to a method for mooring the tensioning arrangement for a floating structure or vessel.

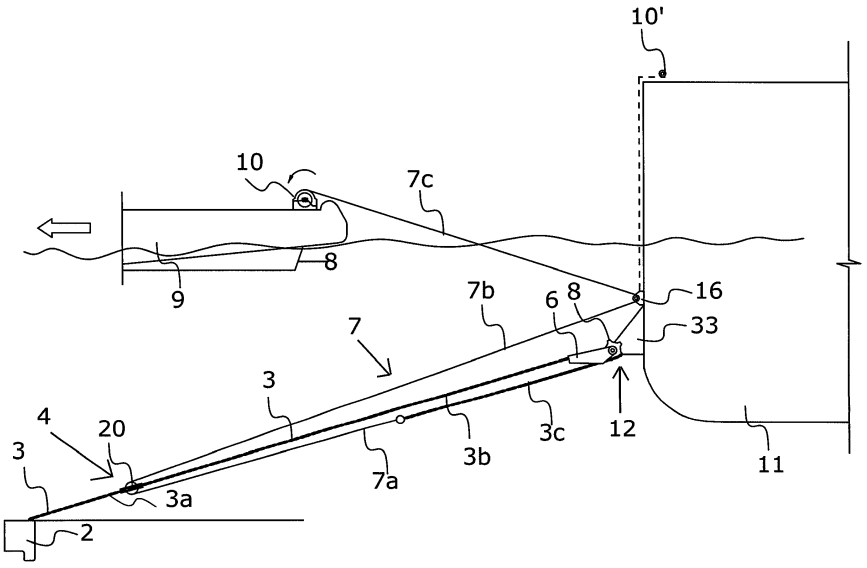

FIG. 2A

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Description

Field of invention

[0001] The present invention relates to mooring and tensioning of mooring lines for floating structures or vessels, such as Floating Production, Storage and Offloading vessels (FPSO's), semi-submersible platforms, turret moored vessels, floating drilling rigs, drilling ships and other floating structures which are moored to the seabed.

[0002] The invention is more specifically directed to a mooring arrangement and an installation method.

Background of the invention

[0003] Structures and vessels that are supposed to stay moored at the same location for a long time, such as months or years, have to be moored with a prescribed tension. The traditional method is to use chain tensioning equipment on deck for pull-in and tensioning. Normally this equipment is used during the installation period and left on the vessel for a number of years without being used or maintained. When the mooring lines slacken sufficiently over time, due to wear of chains, shifting of anchors, creep in fiber mooring lines etc, the mooring lines have to be re-tensioned, repositioned (typically move the chain one or two chain links in order to engage the chain stopper on a new chain link) or replaced. In this period between installation and next operation, the equipment has normally seized or corroded and requires refurbishment.

Another issue is the weight and deck space. Deck space is often limited and weight on deck is an important factor for the stability of the vessel.

[0004] The aim of this patent application is to provide arrangements and methods where there is little or no requirement for equipment on the deck of the vessel and still be able to perform the installation, tensioning, re-tensioning, repositioning and replacement operations.

[0005] US 2014/0216323 describes a mooring arrangement and a method of installing the mooring arrangement. An anchor chain is attached to the seabed by an anchor. A submerged chain stopper is attached to an upper end of the anchor chain. A pull chain or installation chain extends from the structure to be anchored through the chain stopper. The lower end of the installation chain is pulled upwards by the use of a winch on the support vessel until the installation chain passes through the chain stopper, a prescribed tension is achieved and the chain stopper engages on the permanent part of the mooring line, here described as the work chain.

[0006] The main difference between the above mentioned patents are that the US 2014/0216323 A1 may use a wire from a winch on the anchor handler towards the platform. By doing this it is possible to tension the mooring line with a force based on the winch capacity. The actual tension force will depend on factors such as angle of the mooring chain with respect to the platform and the support vessel. If the mooring line is close to vertical, the effect of this method is close to zero.

[0007] In these references, the arrangement and method are relied on pulling the installation chain of the mooring chain vertically or close to vertically upwards to an installation vessel in order to tension the chain. The benefit of both these systems is that there is no chain and chain handling equipment on the deck of the FPSO. However, the main disadvantages are that all mooring line tensioning requires an installation vessel and fine tuning of each mooring line may be difficult. Additionally the installation requires an additional length of installation chain.

[0008] US 2002/0189522 describes a similar arrangement and method as above. WO 03/013950 also describes a similar mooring arrangement and method.

[0009] It is expensive to use an installation or support vessel every time a re-tensioning of the mooring is required.

[0010] The vertical, or close to vertical, pulling of the chain will also pull the submerged chain tensioner upwards, so that an obtuse angle is created between the chain below the chain tensioner and the chain above the chain tensioner extending between the anchor at the seabed and the moored structure, as can readily be seen in the figures of the two references. The size of this angle will depend on several factors, such as pulling tension, weight of the chain, friction in reversing pulley of the chain tensioner, sea currents etc. Due to the angle, the length of chain between the anchor and the floating structure is somewhat greater than the linear distance between the anchor and the floating structure.

[0011] Especially if the anchor is at a great distance from the floating structure or the water depth is small, the mooring line can extend at a very shallow angle from the seabed. In such cases the pull to tighten the mooring can be almost at right angle to the mooring line. This will result in the angle between the two parts of the mooring line, below and above the chain tensioner, becoming smaller and thus the length of the mooring line during tensioning will become far greater than the direct distance between the anchor and the floating structure.

[0012] When the mooring has been tightened to the prescribed tension, the upper end of the installation chain will be released. Hence, the chain tensioner will sink until it finds itself approximately on the straight line between the anchor and the floating structure. This inevitably leads to a slackening of the mooring. Hence, the mooring must be tightened somewhat beyond the required tension to account for this slackening.

[0013] However, it is difficult to predict how much overtightening is required to achieve the correct tension.

[0014] There are several other disadvantages as well, such as:

- The weight of the chain stopper arrangement may be a problem for the mooring line and the mooring characteristics.

- After the chain installation and tensioning is finished, the excess mooring chain has to be cut to reduce the additional weight midwater. This will typically require a ROV operated subsea chain cutter unit.
- If you want to pay out the mooring chain, the chain stopper will have to be operated with an ROV. The chain tensioning arrangement will typically be located 50 - 100 meters below the surface.

Objectives of the present invention

[0015] The present invention has as a first main objective to avoid additional weight midwater on the mooring line from the chain stopper structure and the excess mooring chain. A wire sheave positioned mid-water has considerable less weight than a chain stopper pulley and excess mooring chain.

[0016] The mid-water sheave may, in an alternative embodiment, be a temporary sheave arrangement, which is removed after the installation has been completed.

[0017] The present invention has as a second main objective to avoid the problem of having to account for a certain amount of overtightening when installing a mooring or re-tensioning a mooring.

[0018] A further objective of the present invention is to provide an arrangement and method for installation, tensioning and replacement of mooring lines where there is no requirement for chain handling on the deck of the floating structure.

[0019] Tensioning can be performed from an installation vessel and in particular smaller vessels due to multiplication of the tensioning force from the pulley arrangement. The multiplication factor is close to 3 depending on actual angle and friction.

[0020] Additionally, a slightly longer work chain can be used instead of an installation chain. An installation wire may act as the main part of the installation chain.

[0021] Yet another advantage of the invention is that the chain tensioning may be operated from the FPSO by a wire, rope or hydraulic cylinder.

[0022] Another advantage of the present invention is that the weight of the excess top chain is carried mainly by the hull bracket.

[0023] A further advantage of the invention is that half of the capacity of the mooring line winch or installation vessel pull is required.

[0024] Yet another advantage of the invention to provide an easy tensioning arrangement for a floating structure with no requirement for chain handling on deck of the vessel and which also requires less/minimum of tensioning force.

Summary of the invention

[0025] The present invention relates in a first aspect to a mooring tensioning arrangement for a floating structure or vessel, wherein the mooring tensioning arrangement comprising an anchor, a mooring line a fairlead chain stopper arrangement arranged on the floating vessel, a midwater pulley device and a pulling unit, said mooring line is attached to the anchor at a first end and attached to the pulling unit at the second end, said mooring line extending from the anchor through the fairlead chain stopper arrangement, said midwater pulley is adapted to be arranged on a part of the mooring line arranged between the anchor and the fairlead chain stopper arrangement, said fairlead chain stopper arrangement comprising a chain stopper interacting with said mooring line and a chain pulley guiding the mooring line through the fairlead chain stopper arrangement and back towards the midwater pulley and from said midwater pulley towards said pulling unit.

[0026] In a second aspect the invention relates to a method for tensioning a mooring arrangement on a floating structure or vessel according to any one of the preceding claims, wherein said method comprising the following steps:

a) transferring an installation wire to and from the pulling unit, said first installation wire is extending through the fairlead chain stopper arrangement,

b) pulling in the mooring chain by the pulling unit,

c) connecting the installation wire and the mooring chain together to a mooring line,

d) lowering the mooring line from the pulling unit into the sea,

e) tensioning the mooring line by the pulling unit and the fairlead chain stopper arrangement,

f) transferring a second installation wire between the floating structure and the pulling unit,

g) extending the mooring line around the midwater pulley,

h) tensioning the mooring line by the pulling unit.

[0027] In a third aspect the present invention ensures that the tensioning force acting upon the mooring line is directed towards the floating structure or vessel, preferably towards the attachment point of the mooring line on the structure or vessel. This ensures that the mooring line extends in a substantially straight line from the anchor to the floating structure or vessel.

[0028] The weight of the mooring line and sea currents will of course influence on the course of the mooring line also in the case of the present invention. Consequently, the mooring line may not extend in a perfectly straight line.

[0029] This object of the invention may be achieved by two somewhat different alternative aspects of a mooring

tensioning arrangement.

Brief description of the drawings

[0030] The foregoing features of the invention will be more readily understood by reference to the following detailed description taken with reference to the accompanying drawings.

Figure 1 shows a mooring tensioning arrangement for a floating structure or vessel according to a first embodiment of the invention.

Figure 2a shows a mooring tensioning arrangement according to a second embodiment of the invention.

Figure 2b shows a detail view of the fairlead and the first pulley device of the present invention according to the first and second embodiment of the invention with a temporary midwater pulley device.

Figure 2c shows a further alternative solution for the fairlead constructions.

Figure 2d shows an alternative embodiment of the fairlead structure according to the invention.

Figures 3 to 21 show typical installation procedures. It should be noted that this is based on an approach where the first part is to get the FPSO storm safe or safely moored sufficiently for the final tensioning to be performed. This means that all the mooring lines shall be connected with a link on the mooring chain to the FPSO. When all the mooring lines are connected, final tensioning can be performed.

Figure 3 shows a first step in the first and second embodiment shown of a method of tensioning according to the present invention.

Figure 4 shows a second step in the first and second embodiment of a method of tensioning according to the present invention, where a forerunner has been installed between the floating structure and the installation vessel.

Figure 5 shows a third step in the first and second embodiment of a method of tensioning according to the present invention, where a first installation wire is replacing the forerunner.

Figure 6 shows a fourth step in in the first and second embodiment of a method of tensioning according to the present invention, where a mooring chain is pulled in by the installation vessel.

Figure 7 shows a fifth step in the first and second embodiment of a method of tensioning according to the present invention, where the first installation wire and mooring chain is connected together at the installation vessel.

Figure 8 shows a sixth step in the first and second embodiment of a method of tensioning according to the present invention, where the connection part between the first installation wire and the mooring chain is lowered down into the sea by lowering means.

Figure 9 shows a seventh step in the first and second embodiment of a method of tensioning according to the present invention, where the lowering means are released from the mooring chain.

Figure 10 shows an eight step in the first and second embodiment of a method of tensioning according to the present invention, where the first installation wire and the mooring chain are tensioned by the installation vessel.

Figure 11 shows a ninth step in the first embodiment of a method of tensioning according to the present invention, where a second installation wire is transferred from the floating structure towards the installation vessel.

Figure 12 shows a tenth step in the first embodiment of a method of tensioning according to the present invention, where the midwater pulley device is coupled to the first installation wire.

Figure 13a-13c show an eleventh step in the first embodiment of a method of tensioning according to the present invention, where the temporary midwater pulley device is connected to the mooring chain.

Figure 14a-e show a twelfth step in a first embodiment of a method of tensioning according to the present invention, where the tensioning of the mooring arrangement is performed. Tensioning with the winch on the installation vessel.

Figure 14a-c show an embodiment with a temporary pulley device.

Figure 14d-e show two different embodiments with permanently arranged pulley device.

Figure 15 shows a ninth step in a second embodiment shown in Figure 2 of a method of tensioning according to the present invention, where an installation wire part is transferred between a second pulley arranged on the floating structure and the installation vessel.

Figure 16a-c shows a tenth step in the second embodiment shown in Figure 2 of a method of tensioning

according to the present invention, where the installation wire part is connected to the installation wire connected to the mooring chain and the temporary midwater pulley device is connected to the installation wire.

Figure 17 shows an eleventh step in the second embodiment shown in Figure 2 of a method of tensioning according to the present invention, where the midwater pulley device is lowered into the sea and connected to the mooring chain.

Figure 18a-d shows a twelfth step in in a second embodiment shown in Figure 2 of a method of tensioning according to the present invention, where the tensioning of the mooring arrangement is performed. Tensioning with the bollard pull of the vessel.

Figure 18a-b shows the embodiment with a temporary pulley device

Figure 18c-d shows embodiments with permanently arranged pulley device.

Figure 19 shows a thirteenth step in the first and second embodiment of a method of tensioning according to the present invention, where the tensioning mooring arrangement is removed from the mooring arrangement.

Figure 20 shows a fourteenth step in the first and second embodiment of a method of tensioning according to the present invention, where the mooring chain is cut to a suitable length.

Figure 21 shows the anchored floating structure or vessel after the tensioning process according to the first and second embodiments.

Figure 22 shows a further alternative configuration of the mooring tensioning arrangement.

Figure 23 shows a still further alternative configuration of the mooring tensioning arrangement.

Figure 24 shows a yet further alternative configuration of the mooring tensioning arrangement.

Figure 25 shows another further alternative configuration of the mooring tensioning arrangement, which is especially adapted for drilling platforms.

Figure 26 shows a possible arrangement of the loose end of the mooring chain after installation.

Detailed description of embodiments of the invention

[0031] The definitions in the application shall be interpreted broadly throughout the application.

[0032] The mooring chain 3 and the first installation wire 7 are referred to as several parts 3a, 3b, 3c and 7a, 7b, 7c throughout the description. This is done to simplify the description of the tensioning mooring arrangement and the different embodiments. The mooring chain parts 3a, 3b, 3c could form one continuous mooring chain 3. The first installation wire 7a, 7b, could likewise form a continuous first installation wire 7. The mooring chain 3 and the first installation wire 7 could also be made of segments joined together.

[0033] The mooring chain 3 and the first installation wire 7could also be joined together in one continuous length. This is referred to as mooring line 3, 7 in the claims.

[0034] The term midwater is to be interpreted broadly and not as an indication that the midwater has to be positioned midwater. The term indicates that the pulley can be installed anywhere on the mooring chain 3 between the anchor 2 and the fairlead chain stopper arrangement 12.

[0035] Figure 1 shows a mooring arrangement according to a first embodiment of the present invention.
The mooring arrangement is installed between an anchor 2 that has been attached to the seabed 1 and a floating structure 11, such as an FPSO. The installation process will be further explained in detailed later.

[0036] The anchor 2 is conveniently a suction anchor, but may alternatively be any type of anchor known in the field.

[0037] The tensioning mooring arrangement further comprises a mooring chain 3, midwater pulley device 4 with a pulley 20, and an installation wire 7. A hull bracket 33, a chain wheel 8 and a chain stopper 6 are arranged in a fairlead chain stopper arrangement 12, which is capable of retaining the mooring chain 3 in tension, preferably at the lower portion of the floating structure 11. Any position on the hull of the floating structure 11 is however possible.

[0038] The mooring chain 3 may also be a steel wire, polyester rope or a combination of these. The mooring chain 3 could be on continuous chain or the chain could be divided by a permanent midwater pulley device 4'. The mooring chain 3 may also comprise several segments of these.

[0039] Conveniently, the chain wheel 8 is attached to the hull bracket 33 by a shaft and the chain wheel 8 may rotate about a vertical axis.

[0040] A chain stopper 6 is also attached to the hull bracket 33. A detailed view of the fairlead chain stopper arrangement 12 comprising the hull bracket 33, chain wheel 8 and the chain stopper 6 are shown in figure 2b. This figure illustrates a second embodiment of the mooring tensioning arrangement (This embodiment is de-

scribed below). The fairlead chain stopper arrangement 12 is however equal in both embodiments of the mooring tensioning arrangements.

[0041] The chain wheel 8 is rotatable connected to a steel structure 26 of the hull bracket 33. The hull bracket 33 further comprises a lower hull support 27 and an upper hull support 28. A vertical shaft 29 connects the steel structure 26 with the supports 27, 28 so that the structure 26 can rotate about a vertical axis.

[0042] The chain stopper 6 is not shown in further detail. The chain stopper 6 comprising a channel through which the mooring chain 3 can pass. The chain stopper 6 may have a single latch or consist of two latches, both are known per se. The latch or latches may operated by a spring which closes the latch or latches towards a closed position to ensure safe closing of the lath or latches.

Opening the chain stoppers 6 may be performed by a permanent hydraulic cylinder, mechanically with lever arm, links and/or wires or as another option with a temporary mechanical or hydraulic tool operated from the FPSO or the vessel performing the chain operation

[0043] From figure 2b it is shown that the fairlead chain stopper 6 is attached to the hull bracket 33 in one end and having a free end extending away from the floating structure 11. In the figure 2b, the chain stopper 6 and the chain wheel 8 are attached to the bracket 33 by a common shaft 34. This connection allows the chain wheel 8 to rotate around its horizontal center axis and the chain stopper 6 to pivot about the same horizontal center axis.

[0044] In figure 2b, the fairlead chain stopper 6 and chain wheel 8 are arranged so that the mooring chain 3 is extending upwards around the chain wheel 8. In Figure 1 a and 2a there are shown a fairlead chain stopper arrangement 12 where the fairlead chain stopper 6 is arranged above the chain wheel 8 so that the chain is extending downwardly around the chain wheel 8. Both these arrangements are possible embodiments of the invention.

[0045] Other connection arrangements between the bracket 33, chain wheel 8 and the chain stopper 6 are also possible. The relation between the chain stopper 6 and the chain wheel 8 must however be such that the mooring chain 3 extending through the chain wheel 8 is always following a straight line that is tangential to the outer circumference of the chain wheel 8 in every position of the chain stopper 6. The chain stopper 6 is preferably also pivotably connected to the bracket 33 so that the lower free end could move due to the direction of the mooring chain 3.

[0046] Figure 2b also shows the connection fairlead construction or chain stopper arrangement 12 and the attachment to the floating structure 11 in further detail. This could also be equal in both the embodiments of mooring tensioning arrangements.

[0047] The hull bracket 33 comprises a lower support 27 and an upper hull support 28. A vertical shaft (not shown) connects the steel structure 26 with the support 27, 27 so that the structure 26 can rotate about a vertical axis.

[0048] A further alternative solution for the fairlead construction is shown in Figure 2c. In this embodiment, the steel structure 26 is connected to the hull via a bracket 33 and a connecting link 30. Two shafts 31, 32 ensures freedom of movement in two planes. Alternatively, the connecting link can be replaced with a shackle.

[0049] In the alternative embodiment of Figure 2d, the connecting link 30 and shaft 32 has been replaced by a connector comprising a male part 34 and a female part 35, the female part 35 being capable of retaining the male part 34 within a hole (not shown) in the female part 35. The female part 35 is rotatable about a horizontal axis with respect to the bracket 33.

[0050] A rope or wire 36 is initially connected at the end of the male part 34. The rope or wire 36 is fed through the hole in the female part, and by pulling the rope or wire 36, the male part 34 can be brought to enter the hole of the female part 35.

[0051] The male connector 34 and female connector 35 will engage automatically or with the intervention of ROV, a diver or by other mechanic means, depending on the environment.

The embodiments of the connection between the chain tensioner and the floating structure or vessel 11 are illustrated without the chain stopper 6. A similar chain stopper 6 as described above are connected to all the embodiments shown in figure 2c and 2d.

The hull bracket 33, structure 26 and shaft 24 and 29 are part of the mooring load line and must be strong enough to carry the mooring load.

[0052] The midwater pulley device 4 is in figure 1 arranged in connection with the mooring chain 3. Preferably, the midwater pulley device 4 is releasable connected to the mooring chain 3, but a midwater pulley device 4 integrated in the mooring chain 3 is also a possible embodiment of the invention. These could be seen in Figure 14d-e and figure 18c-d. In this embodiment, the midwater pulley device 4 is dividing the mooring chain 3 physically into a mooring chain 3a extending between the anchor 3 and the midwater pulley device 4, and a working chain 3b extending from the midwater pulley device 4 towards the floating structure 11. The midwater pulley device 4 is attached to the mooring chain 3a and the working chain 3b in opposite ends of the midwater pulley device 4.

[0053] An embodiment of a releasable midwater pulley device 4 is shown in detail in figure 2b and also figures 12, 13, 14a-d and figures 16a-18b. The midwater pulley device 4 could also be equal in both embodiments of the mooring tensioning arrangement. The midwater pulley device 4 comprising a midwater pulley 20 rotatable coupled to a connector 21. The connector 21 could for instance be a hook or a hooked device 21 suitable to engage with a chain link 3d of the mooring chain 3 as shown in the figure 2b. An ROV may be used to assist this operation.

[0054] The midwater pulley 20 and the connector 21

could for instance be connected to each other via a structure 22. The midwater pulley 20 could for instance be arranged rotatably about a shaft 23 that is mounted in the structure 22 and the connector could form an integrated part of the structure as illustrated in the figure 2b.

[0055] As seen in figure 1, the midwater pulley device 4 is positioned on the mooring chain3 a distance from the floating structure 11. The mooring chain 3 is further divided into three parts to make it easier to describe how the mooring tensioning arrangement is arranged. As described earlier these parts could form one continuous mooring chain 3 from the anchor to the first installation wire 7.

[0056] The mooring chain 3 is in one end attached to the anchor 2 at the seabed 1. The mooring chain 3 is extending from the anchor 2 through the chain stopper 6 and around the chain wheel 8 of the fairlead chain stopper arrangement 12. This part of the mooring chain 3 have numeral 3a and 3b. The mooring chain 3 further extends back along the mooring chain part 3b. The mooring chain part 3c is attached to a first installation wire part 7a between the midwater pulley device 4 and the fairlead chain stopper arrangement and the first installation wire 7 is further extending as a first installation part 7b around the midwater pulley 20 back to the wire pulley 16 and then towards a support vessel or installation vessel 9. The first installation wire 7 is connected to the installation vessel 9 in a number of possible ways.

[0057] For instance, could the first installation wire 7 be connected to a winch 10, 42 on the support vessel, fixed by shark jaw 51, 52 or loosely connected to the support vessel 9. The first installation wire 7 could also be connected to a winch 10' at floating structure.

[0058] In addition to the arrangement with the mooring chain 3, the embodiment of figure 1 also comprising a second installation wire 14. The second installation wire 14 is extending between a fixed point 13 on the floating structure 11 and the installation vessel 9. The fixed point 13 could for instance be a steel plate with a hole therethrough, a mooring ring or mooring post, etc. arranged on the hull of the floating structure. 11. The second installation wire 14 is preferably connected to a winch 10, 42 or other pulling equipment on the support vessel.

[0059] In the figure 1, the fairlead chain stopper arrangement 12 is arranged below the seawater 15. The fixed point 13 for the second pull-in wire 14 is arranged above the seawater. This is for illustration only. Other positions for the chain stopper arrangement 12 and the fixed point are possible.

[0060] Figure 2a shows the tensioning mooring arrangement according to a second embodiment of the invention. Features that are equal in the two embodiments have the same numeral in the figures.

[0061] The embodiment of figure 2a is similar to the arrangement shown in figure 1 except that the first installation wire 7 is extending between the midwater pulley 20 and a second pulley 16 arranged on the floating structure 11 before the first installation wire 7 is coupled to the support vessel 9.

[0062] This arrangement replaces the fixed point 13 with the second pulley 16 and the independently arranged second installation wire 14 with a first installation wire part 7c which is an elongation of the pull-in wire or installation wire part 7a and 7b from the first embodiment.

[0063] Figure 2b shows the embodiment in detail. The positioning of the second wire pulley 16 could be anywhere on the hull of the floating structure, either close to the chain tensioner as indicated in figure 2a or a distance from the chain stopper arrangement 12 as shown in Figure 2b. The second wire pulley 16 may be situated above the chain stopper arrangement 12, but may also be situated on the same level next to the chain stopper arrangement 12 or even below.

[0064] An installation sequence according to the invention will now be described.

[0065] Figure 3-10 are common installation sequences for both embodiments in figure 1 and 2. Figure 11-14 shows the further installation sequences to the embodiment shown in figure 1. Figure 15 - 18 shows the further installation sequences to embodiment shown in figure 2. Figure 19-21 shows the sequences after tensioning the mooring arrangement when the wire pulley(s) are removed. These sequences are also common in both embodiments.

[0066] During the installation, a number of additional ropes, wires and winches than described above are typically used. These items will be described below. However, other additional conventional equipment may be used, and this shall not limit the method.

[0067] Figure 3 shows the floating structure 11 at the start of the installation of the mooring tensioning arrangement. A forerunner 40 of the first installation wire 7 has been led through the chain wheel pulley 8 and the chain stopper 6. The installation vessel 9 or specialized anchoring vessel has installed the anchor 2 at the seabed 1. Typically, the mooring chain 3 has been left on the seabed attached to a rope 37 (figure 6) with a buoy (not shown) at the free end.

The installation vessel 9 having one or more winches 10, 42 (first and second winch) and one or more shark jaws 51, 52 (first and second shark jaw) to facilitate the mooring pull-in and tensioning operation.

[0068] As shown in Figure 4, both ends of the forerunner 40 are transferred from the floating structure 11 to the installation vessel 9. One end of the forerunner 40 is then connected to a first installation wire 7, which is connected to a second winch 42. The other end of the forerunner 40 is then connected to a first winch 10 or other connecting arrangements on the installation vessel 9. The forerunner 40 is extending over the shark jaws 51, 52 on the installation vessel 9. The winch 10 is pulling in the forerunner 40 which result in that the installation wire 7 is run through the chain wheel 8 and around the chain stopper 6, replacing the forerunner 40 as shown in figure 5. The shark jaw 51 is locking the installation wire 7 in a fixed position after replacing the forerunner 40 in the ar-

rangement.

[0069] As shown in figure 6 the rope 37 and buoy connected to the mooring chain 3 has been picked up and the first winch10 of the installation vessel 9 is pulling in the mooring chain 3. The installation wire is maintained in the fixed position be the shark jaw 51.

[0070] Figure 7 shows the step of connecting the mooring chain 3 and on end of the first installation wire 7 together. The mooring chain 3 disconnected from the first winch 10 and held in a fixed position in the shark jaw 51 before connection with the installations wire 7. The other end of the installation wire 7 is connected to the second winch 42.

[0071] As shown in Figure 8 the connected mooring chain 3 and the first installation wire 7 is lowered from the installation vessel 9 into the sea. This could preferably be performed by a hook 43 that is connected to a hook wire 44. The first winch 10 could pay out the hook wire 44. This ensures a safe and controlled lowering of the mooring chain 3 together with the first installation wire 7 into the sea.

[0072] The mooring chain 3 and installation wire 7 are lowered down from the installation vessel 9 until there is no tension on the hook 43. The hook 43 is then released. The releasing of the hook 43 could for instance be performed by an ROV 45. This is shown in figure 9. The releasing of the hook 43 could also be performed by paying out the hook 43.

[0073] As shown in Figure 10 the mooring chain 3 with the first installation wire 7 is pulled in by the second winch 42 so that the mooring chain 3 extends through the chain stopper 6 and around the chain wheel 8.

[0074] At this point the floating structure 11 is storm safe but the mooring is not final assuming the pretension requirement exceeds the bollard pull of the installation vessel 9. The installation wire 7 is now held in a fixed position in the second shark jaw 52 and could be disconnected from the second winch 42.

[0075] Figure 11 shows the next mooring tensioning sequence according to the first embodiment of the invention. The second installation wire 14 is fixedly attached to the hull of the floating structure 11 in the fixed point 13 in one end.

[0076] The opposite free end of the second installation wire 14 is transferred to the second winch 42 on the installation vessel 9.

[0077] In this sequence, the installation vessel 9 is moved closer to the floating structure 11. The chain stopper 6 prevents the movement of the parts of the mooring chain 3a and 3b between the anchor 2 and the chain stopper arrangement 12. The tension of the mooring chain part 3a and 3b between the anchor and the chain stopper 6 is maintained.

[0078] The part of the mooring chain 3c and the installation wire 7 will however become slack as shown in the figure 11. This part is connected to the installation vessel 9 through the second shark jaw 52 as described above In figure 12 there is shown the connection of the midwater pulley device 4 and the first installation wire 7. The first installation wire 7 is extending around the midwater pulley 20 of the midwater pulley device 4. When the pulley arrangement is to be lowered towards the mooring chain 3, the installation wire 7 has to be locked to the pulley 4. This may be done any type of brake, clamp or similar. The midwater pulley device 4 is then lowered down towards the part of the mooring chain 3a and 3b extending between the anchor 2 and the chain stopper arrangement 12. In this embodiment it is not necessary to use an additional crane or the winches to lower the midwater pulley device 4. The midwater pulley device 4 is then engaging with the mooring chain 3. This is shown in figure 13a-13c. The connection between the mooring chain 3 and the midwater pulley 4 could preferably be performed by a ROV 45.

[0079] In Figure 14a-14b, a further tensioning of the mooring arrangement is performed by the winch pulling the vessel 9 further towards the floating structure 11. The movement of the installation vessel 9 towards the floating structure result in a tensioning force in the installation wire 7b, which again forces the pulley 4 to move, thus increasing the tension in the mooring line 3a. The installation wire 7 is in one end attached to the mooring chain 3 and in the opposite end attached to the installation vessel by the first or second winch 10, 42 or first or second shark jaws 51, 52 or any other fixed point on the installation vessel.

[0080] The second installation wire 14 could in this tensioning position be fixed between the floating structure 11 and the installation vessel 9 and the winch 10 could be used to pull in the installation wire 7b. The second installation wire 14 could in one end be connected to the fixed point 13 on the floating structure 11 and on the other end attached to the first or second winch 10, 42.

[0081] In Figure 14c the tensioning may be performed by a fixed length of wire 14 between the vessel 9 and the floating structure 11. The installation wire 7b is pulled in by a winch 10, 42 obtaining basically the same result as above.

[0082] Figure 14d and 14e shows the same mooring tensioning step as figure 14a-14c. Instead of a temporary midwater pulley device 4, there is a permanent midwater pulley device 4', 4". The permanent midwater pulley device 4' could be an integrated part of the mooring chain 3, dividing the mooring chain physically in two parts 3a and 3b as described earlier and shown in Figure 14d or the midwater pulley device 4" could be fixedly attached to the mooring chain in other ways as shown in Figure 14e.

[0083] The sequence step of the second embodiment after the tensioning of the mooring chain 3 from figure 10 are illustrated in figure 15-18.

[0084] Figure 15 shows the transfer of the first installation wire 7c from the floating structure 11 to the installation vessel 9. A forerunner 40 is extending around the wire pulley 16 arranged on the floating structure 11 and both ends of the forerunner 40 are transferred to the in-

stallation vessel 9. The first installation wire part 7c is then connected to one end of the forerunner 40 and is pulled around the wire pulley 16 by the second winch 42. One end of the first installation wire part 7b is transferred from the first winch10 to the second shark jaw 52 where it is held in a fixed position before connecting with the first installation part 7a

The first installation wire part 7a is held by the first or second shark jaw 51, 52 in a fixed position similar as in the embodiment described in Figure 10 before the connection.

[0085] The installation wire 7c is then connected in one end to the installation wire part 7a that has in a previously step been connected to the mooring chain 3. This is shown in Figure 16a.

[0086] In addition, the midwater chain pulley device 4 is connected to the first installation wire 7 in a similar way as disclosed in figure 12 by extending the installation wire 7 around the midwater pulley 20.

[0087] As shown in Figure 16b-16c, the midwater pulley device 4 is then lowered down to the mooring chain 3a and 3b extending between the anchor 2 and the chain stopper arrangement 12. This may be done in a similar way as in the first embodiment shown in figure 13 by the additional crane or the first winch 10 on the installation vessel and the midwater wire 46. The midwater pulley device 4 is then engaging with the mooring chain 3. This can be done in a similar way as in the first embodiment by the ROV 45.

[0088] Figure 17 shows the attached temporary midwater pulley 4 connected to the mooring chain 3.

[0089] In Figure 18a-d the tensioning of the mooring arrangement is performed. The installation vessel 9 is moved away from the floating structure 11 and at the same time pulling the installation wire 7 and mooring chain 3, increasing the tension in the mooring chain 3. Alternatively, the installation vessel may 9 may stay in position, using its thrust or bollard pull to balance the force from the winch 42 pulling in, thus creating the same increase in tension of the mooring chain.

[0090] Figure 18a-b shows the tensioning mooring arrangement with a temporary midwater device 4 similar as described in figure 2b and in figure 14a-14c.

This embodiment of the tensioning mooring arrangement could also have permanent midwater pulley devices 4', 4" either integrated in the mooring chain 3 as shown in Figure 18c (similar as described in Figure 14d or other ways attached to the mooring chain 3 as shown in Figure 18d . (Similar as described in Figure 14e).

[0091] The Figure 19 -21 discloses the sequences after the tensioning sequences of the mooring chain is shown. The first installation wire 7 is removed from the midwater pulley device 4, 4', 4". In the second embodiment where the first installation wire 7 was extending around the wire pulley 16 as well, the first installation wire 7 must also be released from the wire pulley 16. The first installation wire 7 connected to the mooring chain 3 is pulled in by the winch 10 or 42 on the installation vessel 9. It is only the excess mooring chain part 3c that is not tensioned between the anchor 2 and the chain stopper 6 that being pulled in by the installation vessel 9.

[0092] Figure 20 shows the sequence where a part of the mooring chain 3c that is not tensioned in the mooring arrangement is moved onto the deck of the installation vessel 9 and held in a fixed position by the shark jaw 51, 52. In this sequence the superfluous mooring chain 3 is cut off.

[0093] A smaller part of the mooring chain 3c will be left hanging from the chain stopper arrangement 12 as shown in Figure 21.

[0094] A part of the first installation wire 7 could also possible be connected to the short piece of the mooring chain 3c so that it is easier to access the mooring chain 3c in the next tensioning mooring process. This is also shown in Figure 21.

[0095] Figure 22 shows an alternative configuration of the mooring tensioning arrangement, where the mooring chain 3 has been fed above the fairlead sheave 8 and down to an auxiliary sheave 40 below the fairlead chain stopper arrangement 12.

[0096] Figure 23 shows a further alternative arrangement where the mooring chain 3 has been fed through the fairlead chain stopper arrangement 12 in the same direction as in figure 2b, but the up to an auxiliary sheave 41 arranged above the fairlead chain stopper arrangement 12 and further to the midwater pulley device 4, 4', 4".

[0097] Figure 24 shows yet a further alternative arrangement where a tackle arrangement 42 is couple between the fairlead chain stopper arrangement 12 and a fixed point 43 on the floating structure above the fairlead chain stopper arrangement 12.

[0098] Figure 25 shows the installed mooring chain 3 with an emergency release mechanism 44 on the mooring chain between the fairlead chain stopper arrangement 12 and the anchor (not shown). This is convenient if the floating structure 11 must be quickly removed from the site in an emergency situation.

[0099] Figure 26 shows a possible arrangement of the loose end of the mooring chain3 after installation. The figure show that the chain 3 has simply been cut or otherwise disconnected from the pull-in line 7 and hangs freely downwards. Alternatively the loose end may be fixed to the structure somewhere in the vicinity of the fairlead chain stopper arrangement 12.

[0100] It is to be understood that the present invention is not to be limited by the embodiments of the invention described herein. Indeed, those skilled in the art will readily understand that various modifications and embodiments of the invention may be made and practiced without departing from the scope of the invention.

Claims

1. A mooring tensioning arrangement for a floating structure or vessel, **characterised in that** the moor-

ing tensioning arrangement comprising an anchor (2), a mooring line (3, 7), a fairlead chain stopper arrangement (12) arranged on the floating vessel (11), a midwater pulley device (4, 4', 4") and a pulling unit (9, 10, 42, 51,52), said mooring line (3,7) is attached to the anchor (2) at a first end and attached to the pulling unit (9, 10, 10', 42, 51,52) at the second end, said mooring line (3) is extending from the anchor (2) through the fairlead chain stopper arrangement (12), said midwater pulley (4, 4',4") is adapted to be arranged on a part of the mooring line (3, 7) arranged between the anchor (2) and the fairlead chain stopper arrangement (12), said fairlead chain stopper arrangement (12) comprising a chain stopper (6) interacting with said mooring line (3, 7) and a chain pulley (8) guiding the mooring line (3) through the fairlead chain stopper arrangement (12) and back towards the midwater pulley (4, 4', 4") and from said midwater pulley (4, 4', 4") towards said pulling unit (9, 10, 10', 42, 51, 52).

2. A mooring tensioning arrangement according to claim 1, wherein the mooring line (3, 7) comprising a mooring chain (3) and a installation wire (7), said mooring chain extending at least between the anchor (2) and the fairlead chain stopper arrangement (12) and the first installation wire (7) is attached to said mooring chain (3) and extending at least through the midwater pulley device (4, 4', 4") to said pulley unit (9, 10, 10', 42, 51, 52).

3. A mooring tensioning arrangement according to claim 1, wherein the mooring line (3, 7) having a first flight (3a, 3b) extending between the anchor (2) and the fairlead chain stopper arrangement (12) and a second flight (3c, 7a) extending between the fairlead chain stopper arrangement (12) and the midwater pulley device (4, 4', 4"), said second flight (3c, 7a) of said mooring line (3, 7) is substantially parallel to said first flight (3a, 3b) of said mooring line (3, 7).

4. A mooring tensioning arrangement according to claim 1, 2 or 3, wherein the arrangement further comprising a second installation wire (14) fixedly attached to the floating structure (11) at a first end and attached to the pulling unit (9, 10, 42, 51,52) at the opposite, second end.

5. A mooring tensioning arrangement according to claim 1, 2 or 3, wherein the mooring line (3, 7) comprising a third flight (7b) extending from the midwater pulley device (4) to a second wire pulley (16) arranged on the floating structure (11), said third flight (7b) being an integrated part of the mooring line (3, 7) extending between the second wire pulley (16) and the pulling unit (9, 10, 42, 51, 52).

6. A mooring tensioning arrangement according to claim 1, 2 or 3, wherein the midwater pulley device (4) comprising a connector (20) adapted to be releasable connected to the mooring line (3).

7. A mooring tensioning arrangement according to any one of the claim 1, 2 or 3 wherein the midwater pulley device (4', 4") is fixedly connected to the mooring line (3).

8. A mooring tensioning arrangement according to any one of claims 1, 2 or 3, wherein the chain stopper (6) and the chain pulley (8) being coupled together in a manner such that the part of the mooring line (3, 7) extending through the chain stopper (6) is forming an tangential line to the chain pulley (8) in every possible positions of the chain stopper (6).

9. A mooring tensioning arrangement according to claim 2 or 3, wherein the fairlead chain stopper arrangement (12), said fixed point (13) and/or the second wire pulley (16) are arranged at the hull of the floating structure or the vessel (11).

10. A mooring tensioning arrangement according to claim 1, 2 or 3, wherein said pulling unit is a winch (10, 42) arranged on an installation vessel (9) or on said floating structure.

11. Method for tensioning a mooring arrangement on a floating structure or vessel according to any one of the preceding claims, wherein said method comprising the following steps:

a) transferring an installation wire (7) to and from the pulling unit (9, 10, 42, 51, 52), said first installation wire (7) is extending through the fairlead chain stopper arrangement (12),
b) pulling in the mooring chain (3) by the pulling unit (9, 10, 42),
c) connecting the installation wire (7) and the mooring chain (3) together to a mooring line (3, 7),
d) lowering the mooring line (3, 7) from the pulling unit (9, 10, 42) into the sea,
e) tensioning the mooring line (3, 7) by the pulling unit and the fairlead chain stopper arrangement (12),
f) transferring a second installation wire (7c, 14) between the floating structure (11) and the pulling unit (9, 10, 42),
g) extending the mooring line (3, 7) around the midwater pulley (4, 4', 4"),
h) tensioning the mooring line (3) by the pulling unit (9, 10, 10' 42).

12. Method for tensioning a mooring arrangement on a floating structure or vessel according to claim 11, wherein the method further comprising the step:

i), lowering the midwater pulley device (4) to the mooring chain (3), said step i) is performed before step h).

13. Method for tensioning a mooring arrangement on a floating structure or vessel according to claim 11 or 12, wherein the step further comprising the step:

j) connecting the second installation wire (7c) and the mooring line (3, 7) together at the pulling unit (9, 10, 42, 51, 52)) said step is performed between step f) and g).

14. Method for removing the tensioning arrangement on a floating structure according to claim 1, **characterised in that** said removal comprising the following steps:

a) removing said mooring line (3, 7) from the wire pulley (16) and/or midwater pulley (20),
b) pulling in the mooring line until the mooring chain part (3) is situated on the installation vessel (9),
c) cutting the mooring chain (3) in a suitable length,
d) lowering the remaining chain part (3c) into the sea, said chain part (3c) is hanging from the fairlead chain stopper arrangement (12).

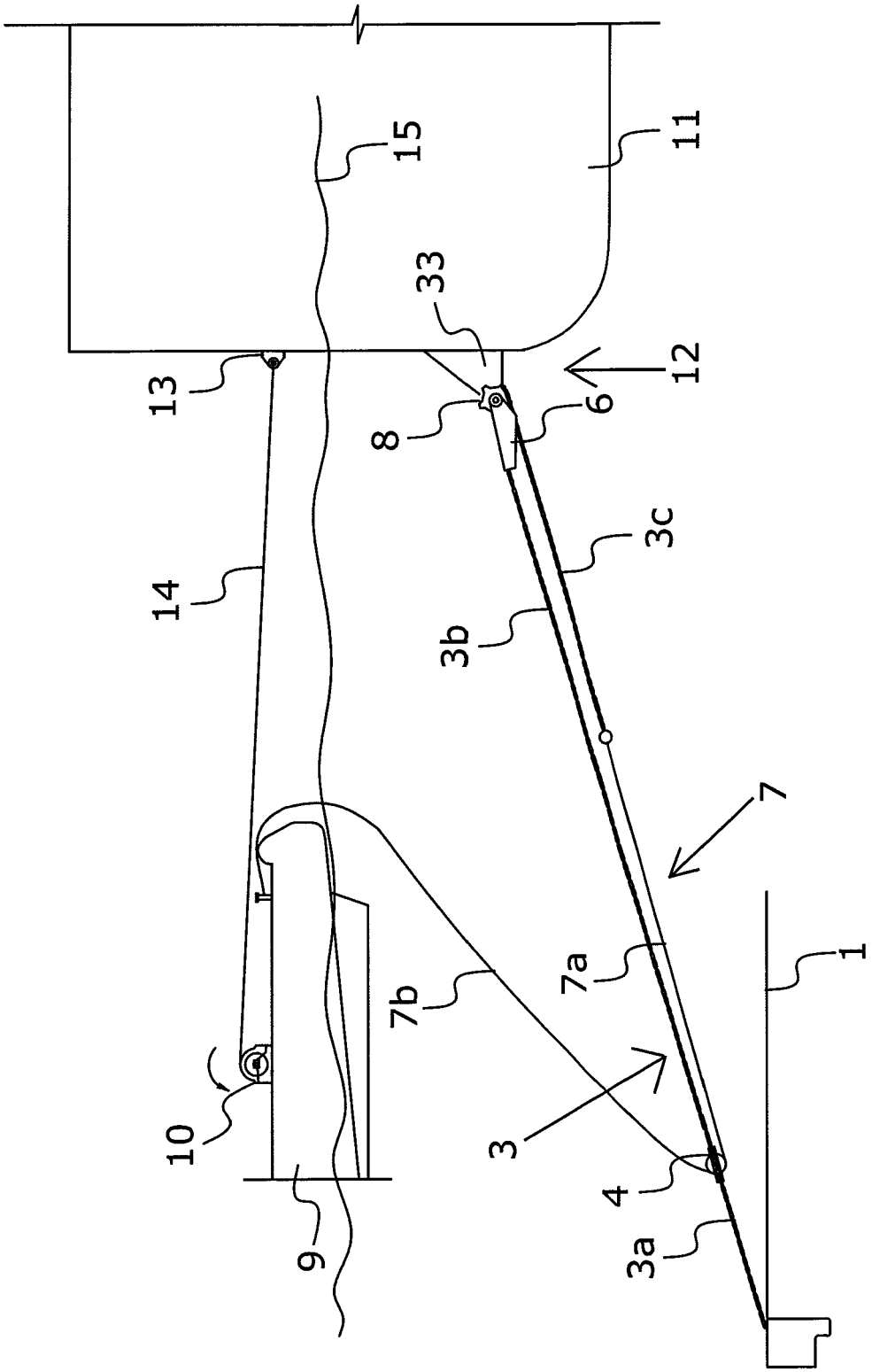


FIG. 1

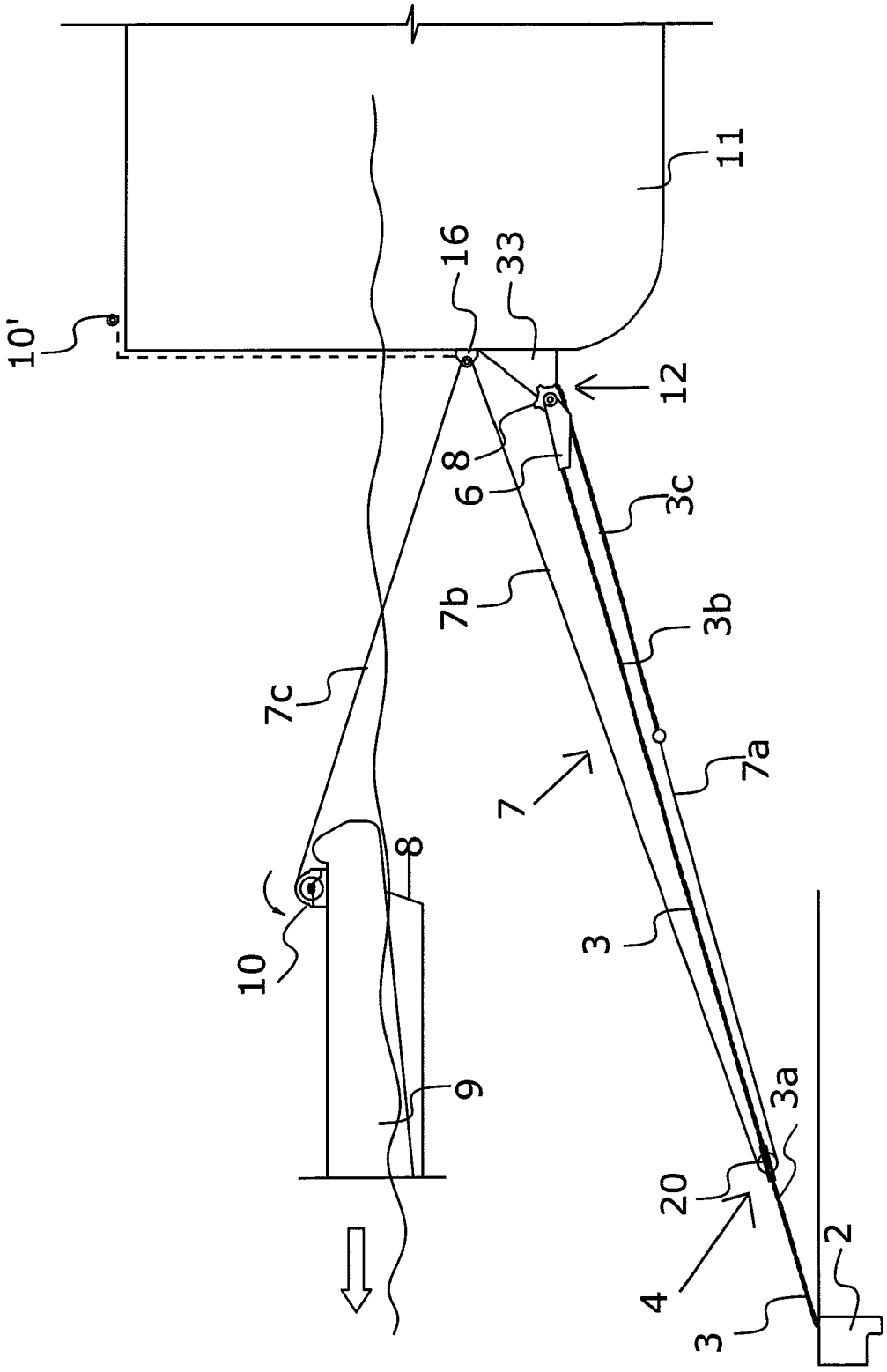


FIG. 2A

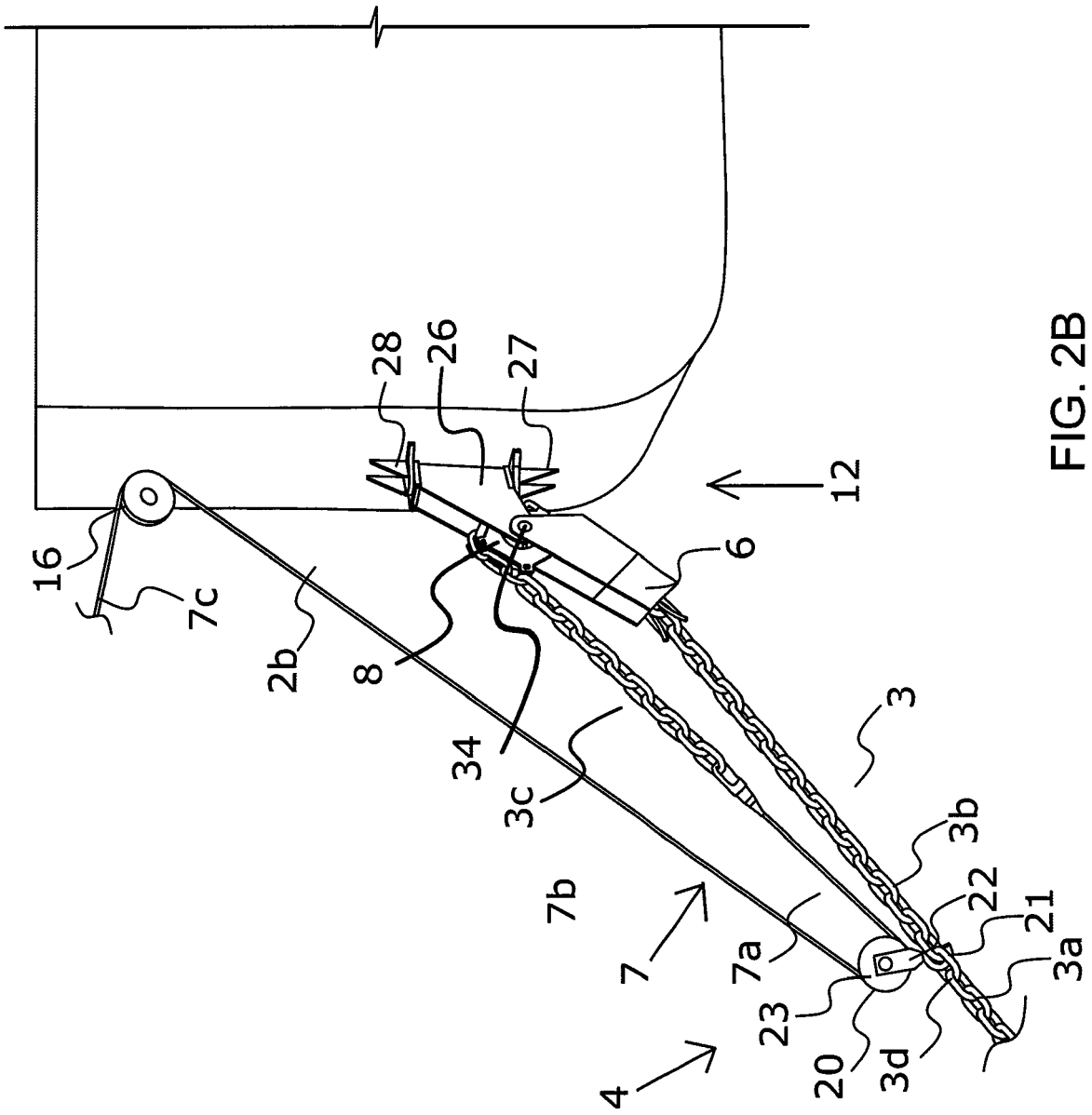


FIG. 2B

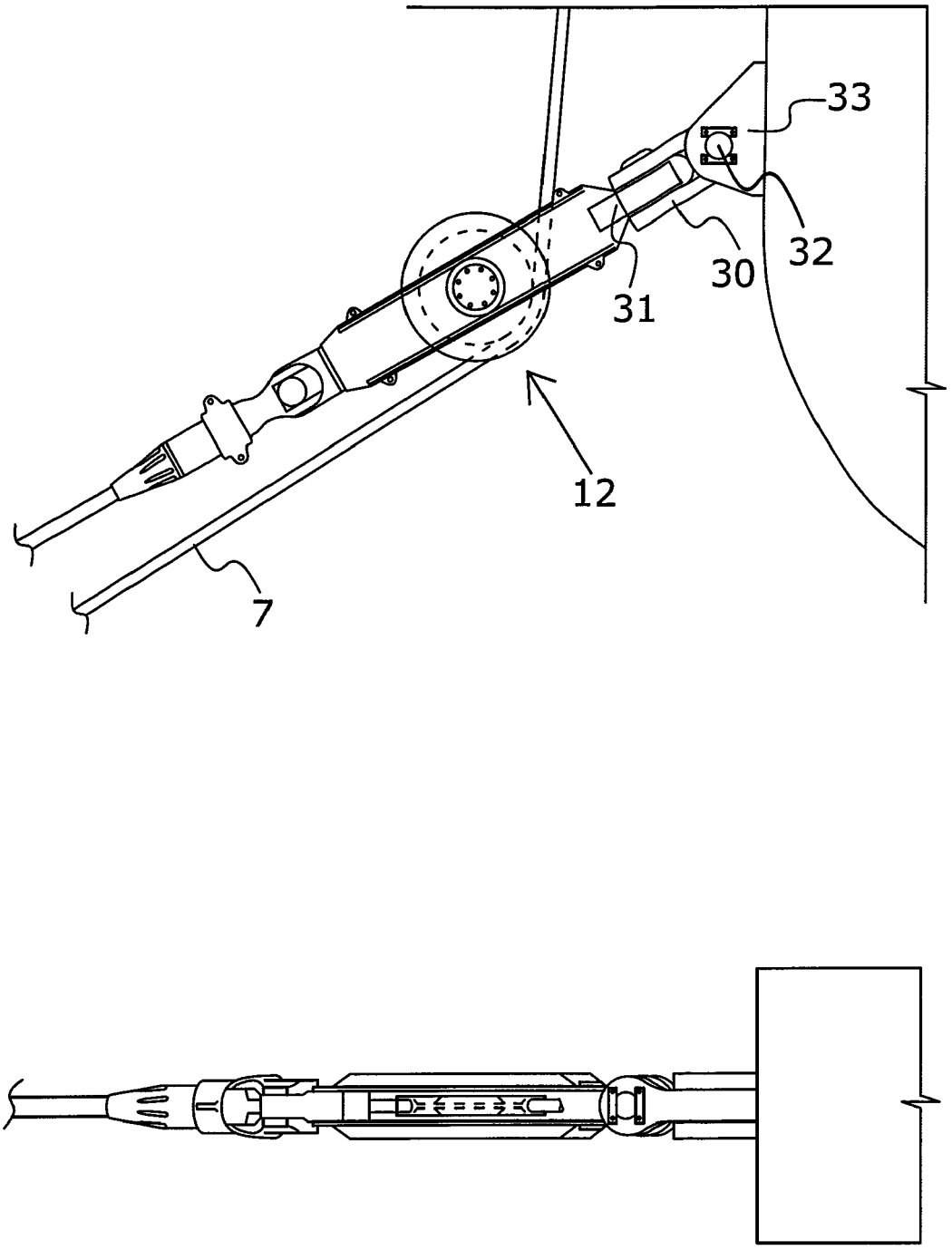


FIG. 2C

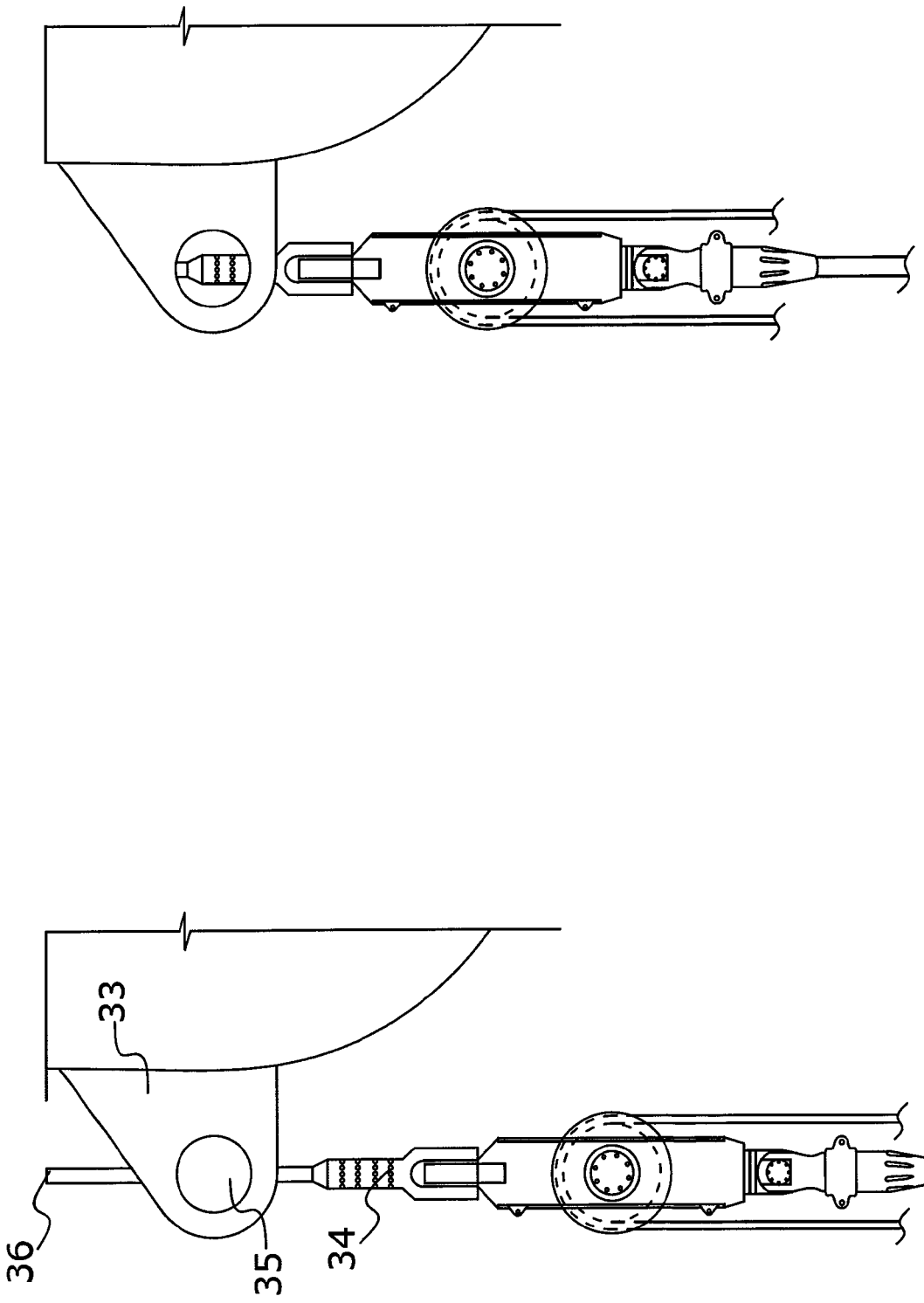


FIG. 2D

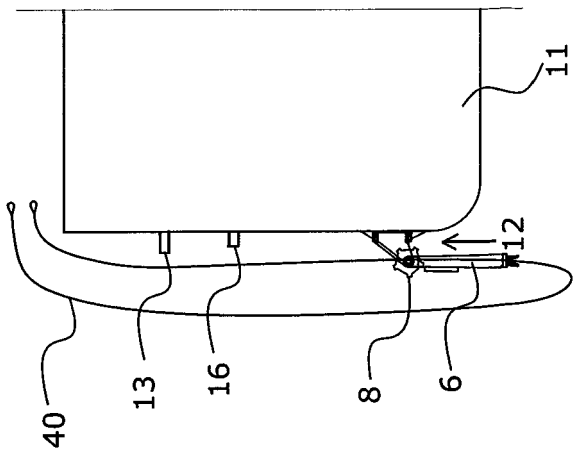
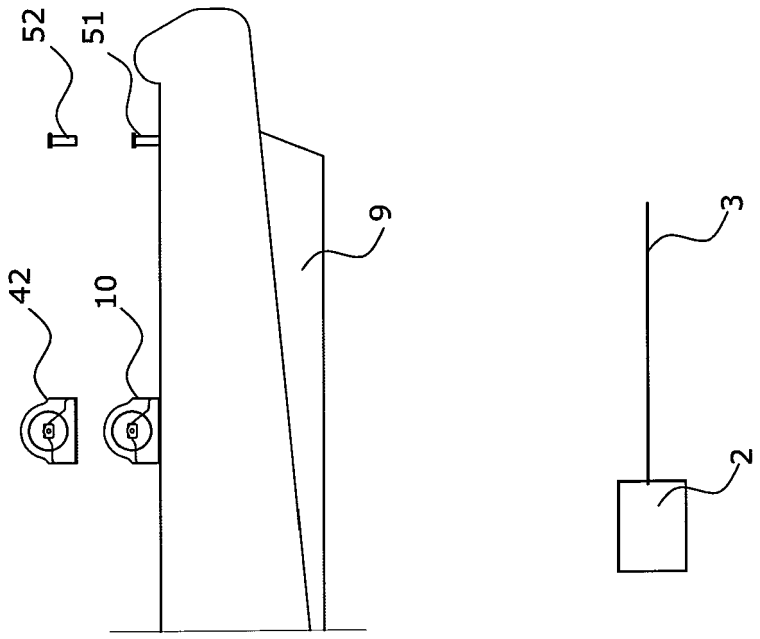


FIG. 3



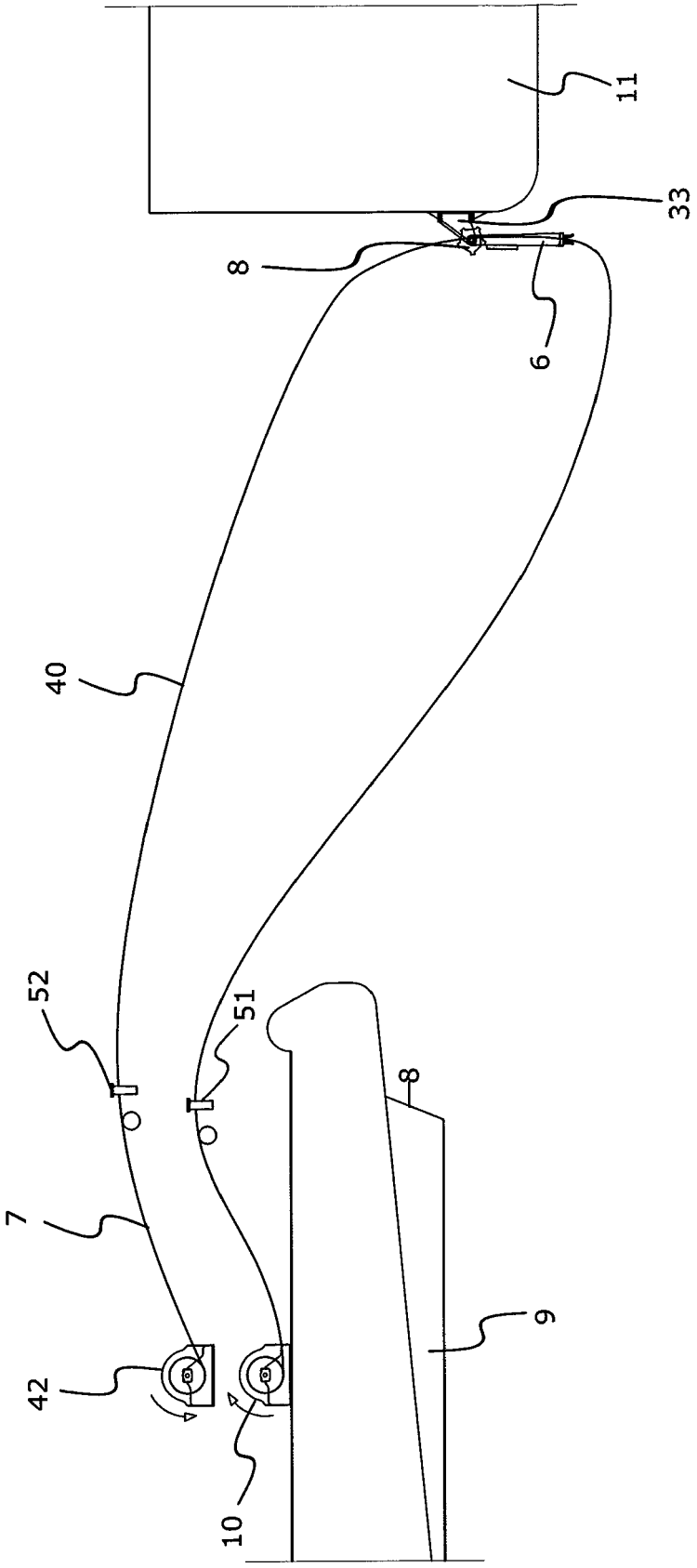


FIG. 4

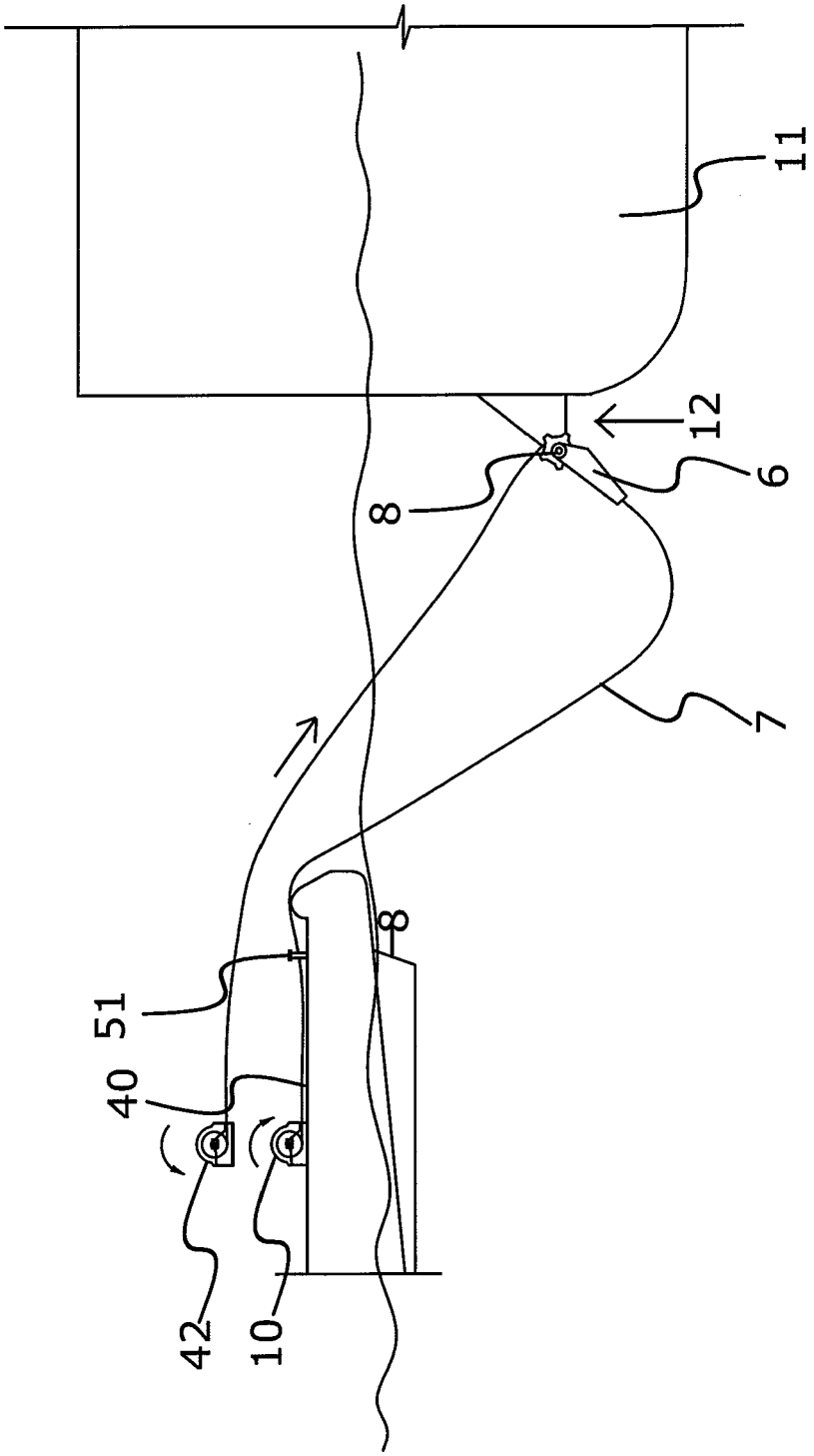


FIG. 5

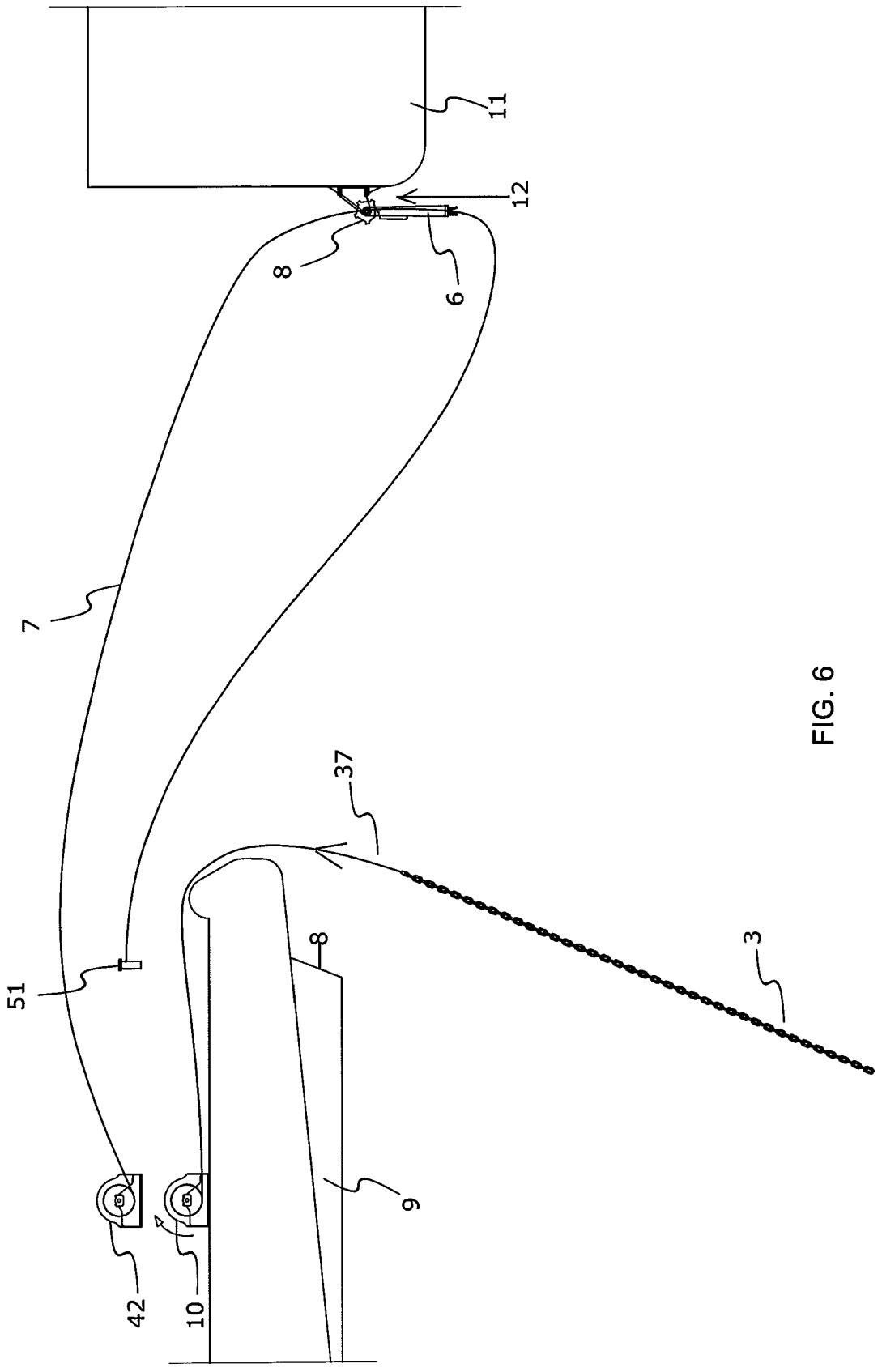


FIG. 6

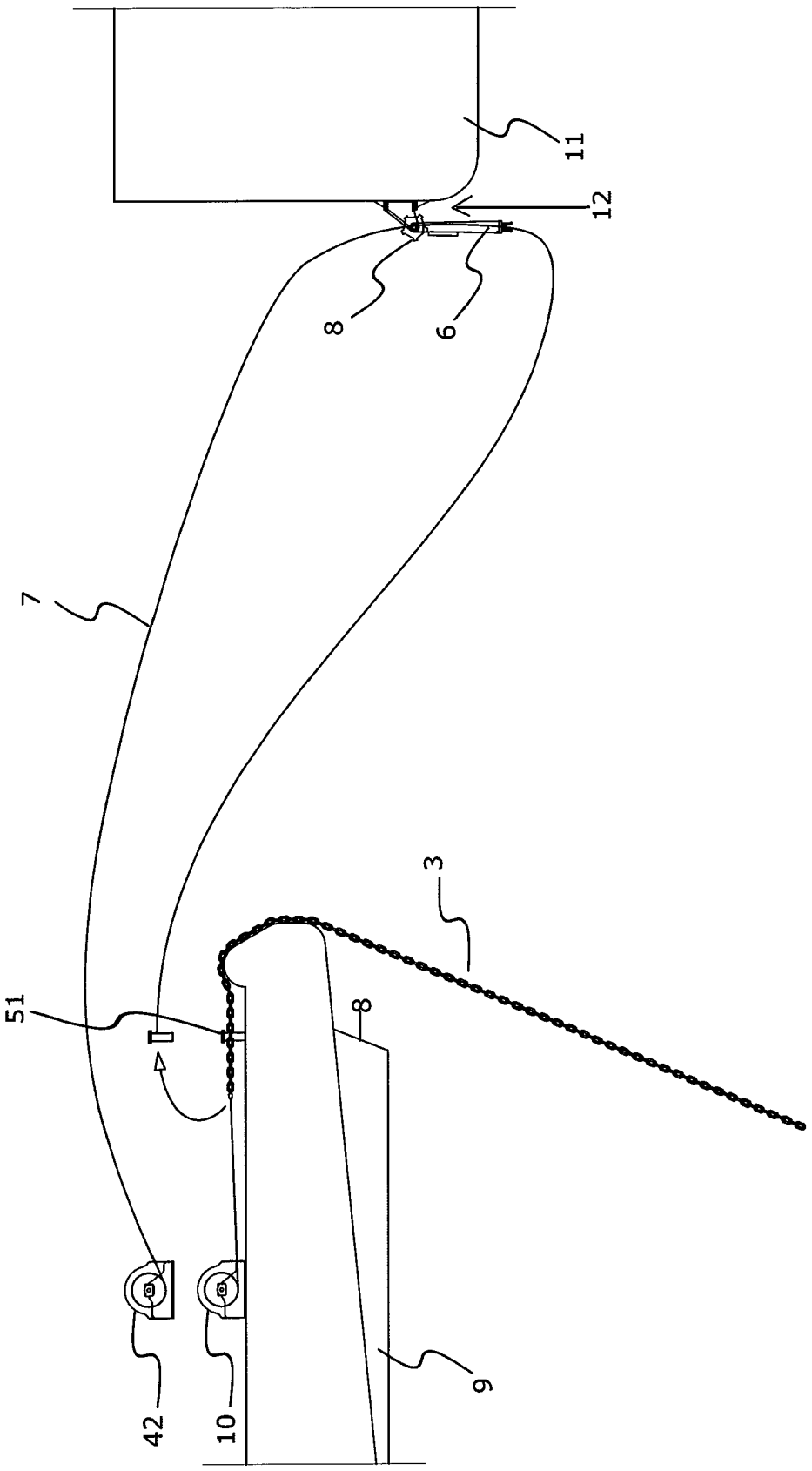


FIG. 7

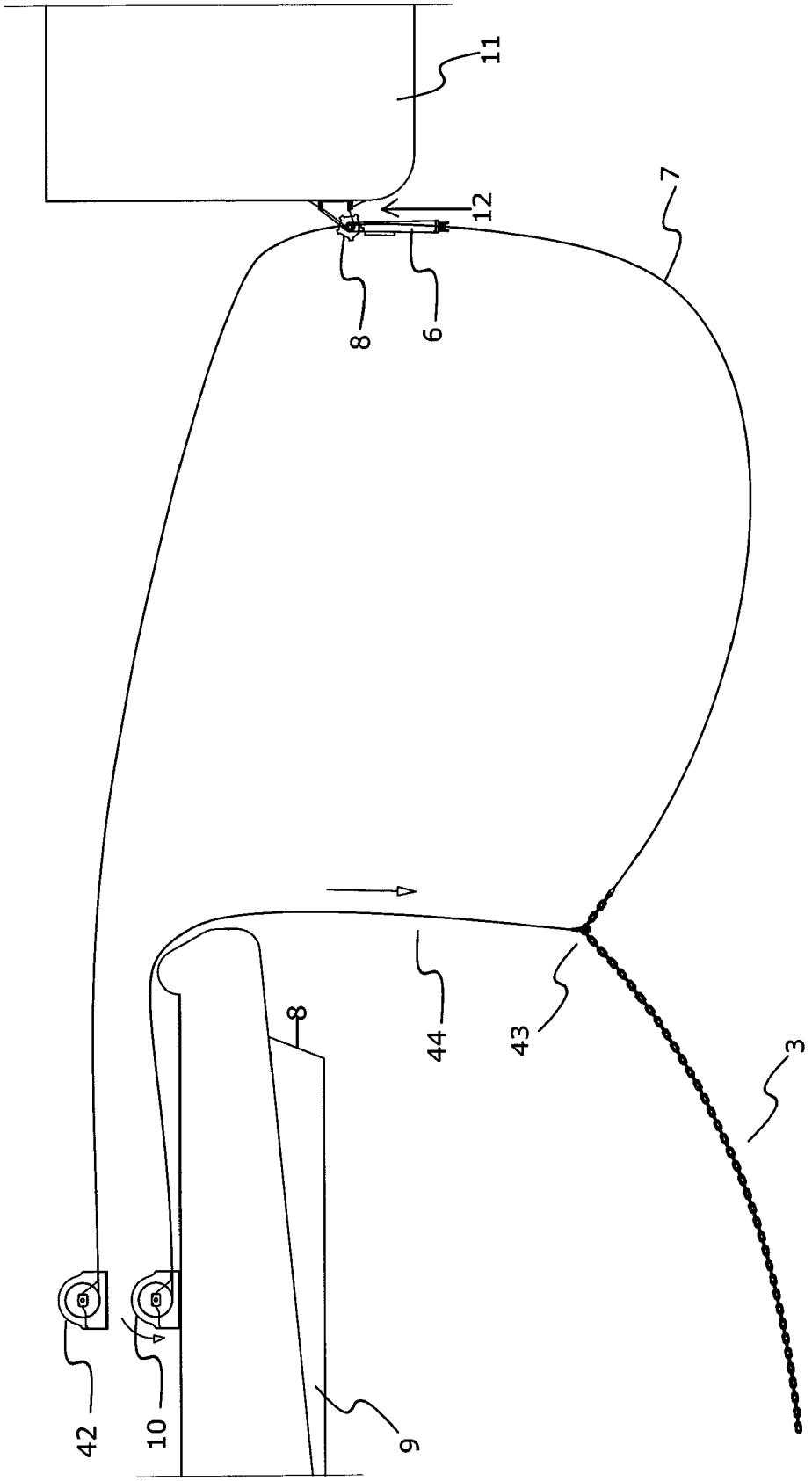


FIG. 8

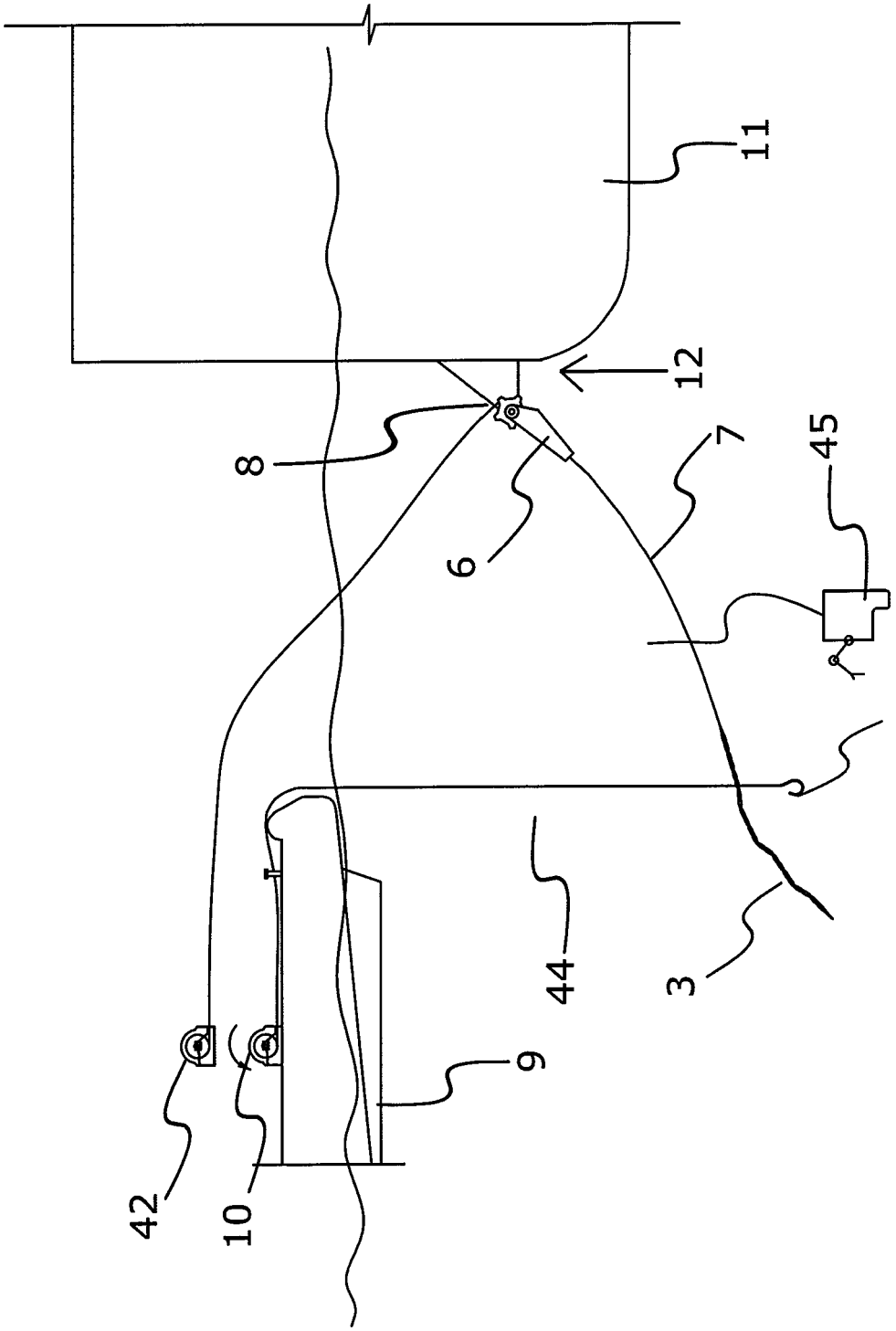


FIG. 9

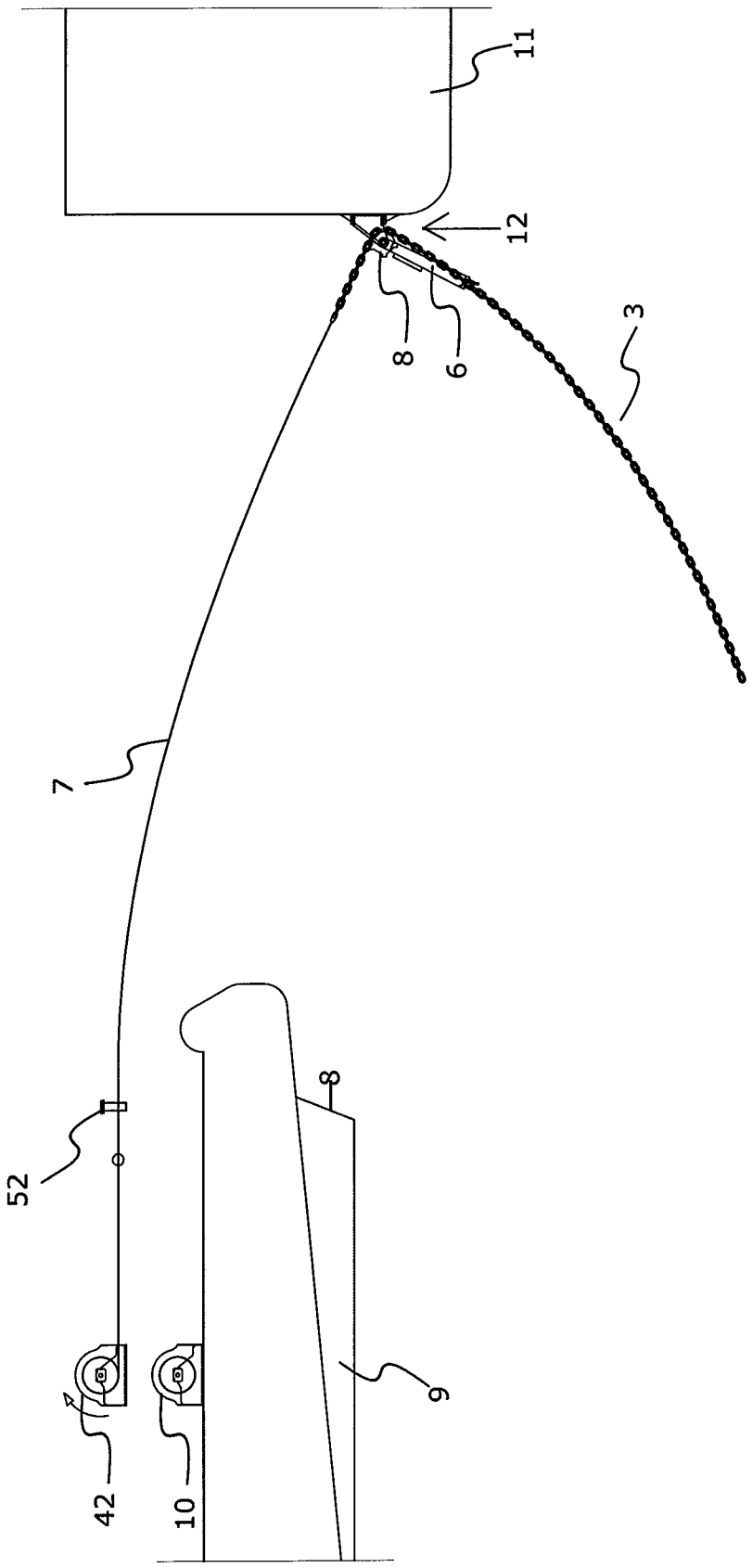


FIG. 10

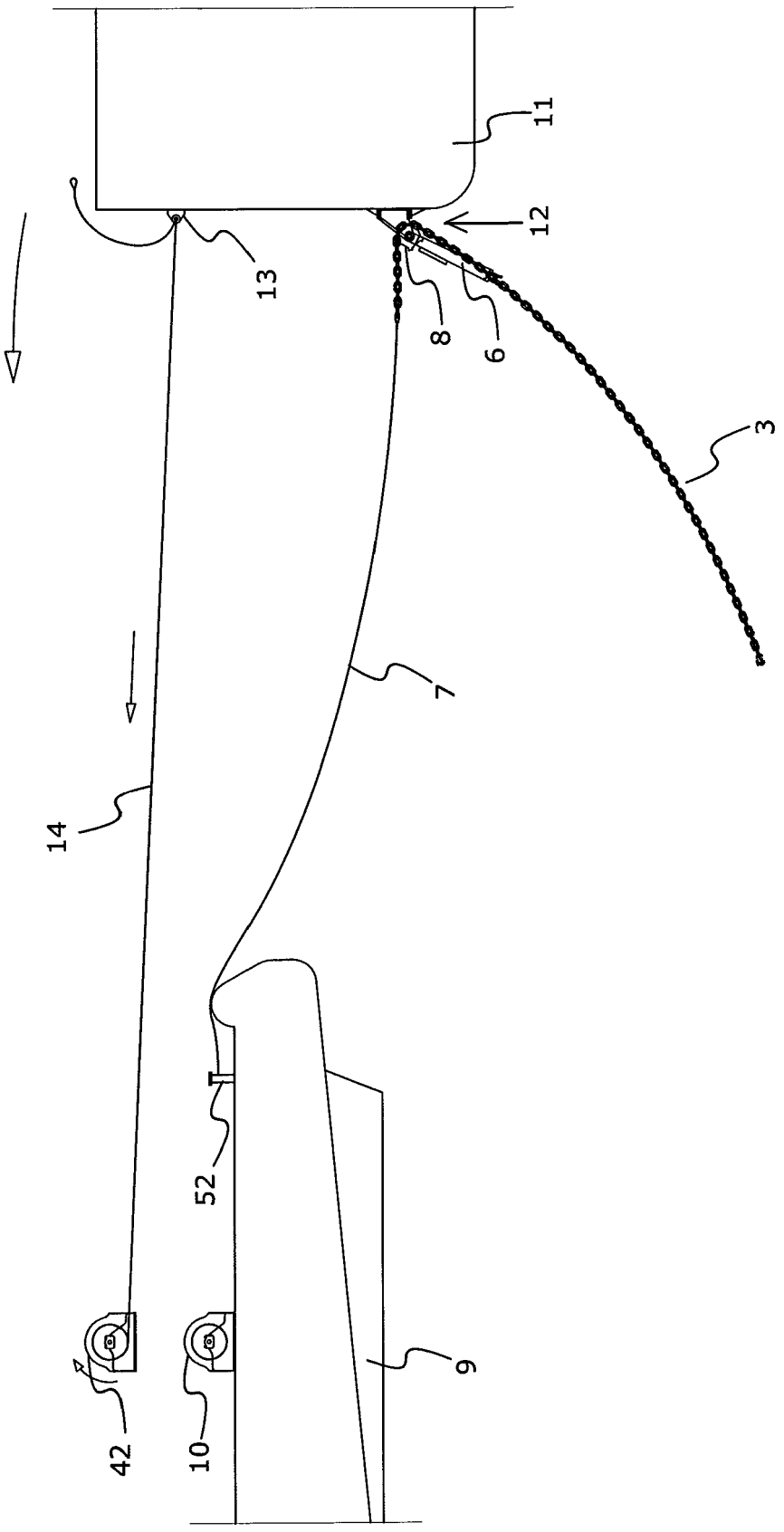


FIG. 11

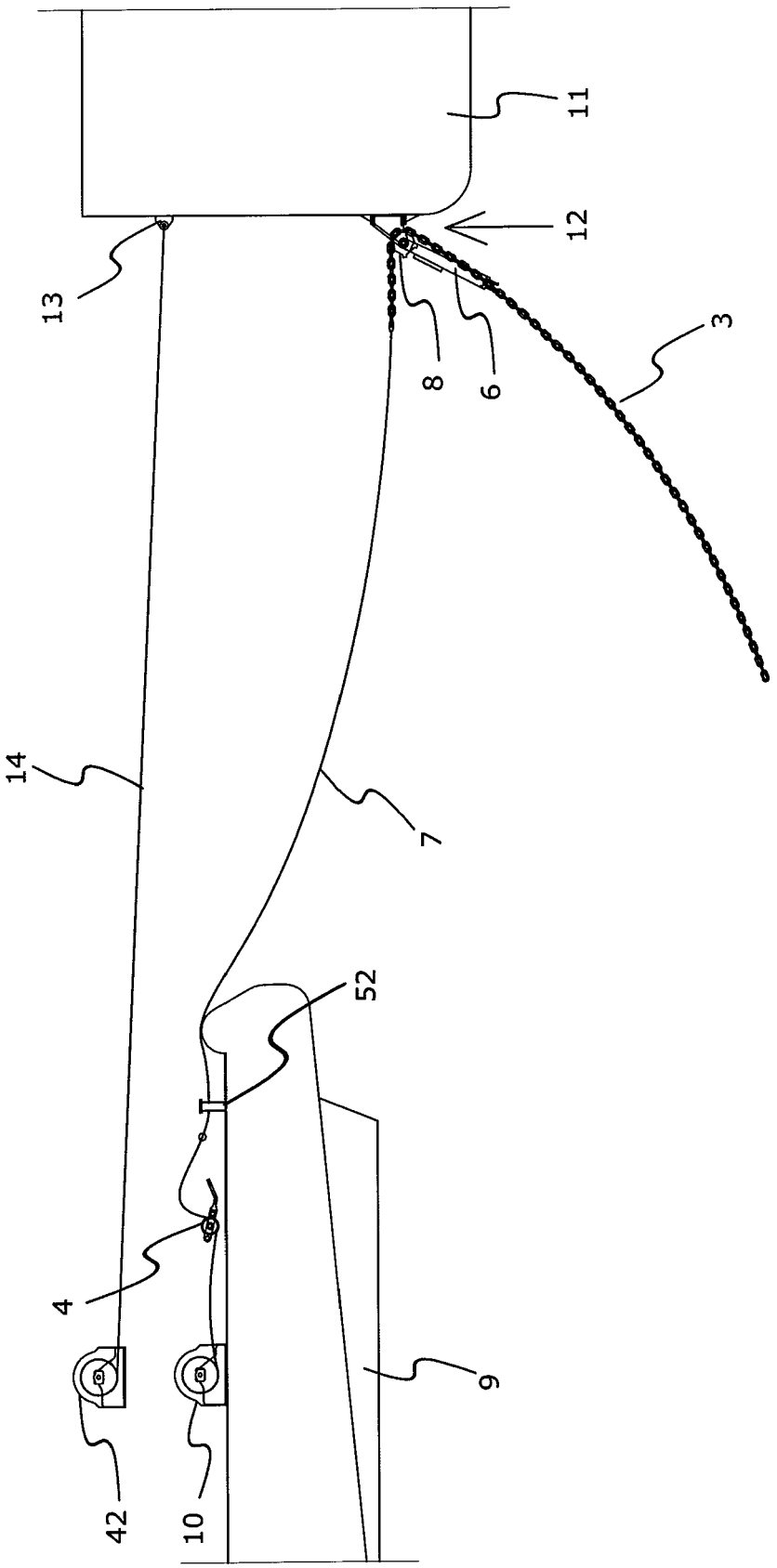


FIG. 12

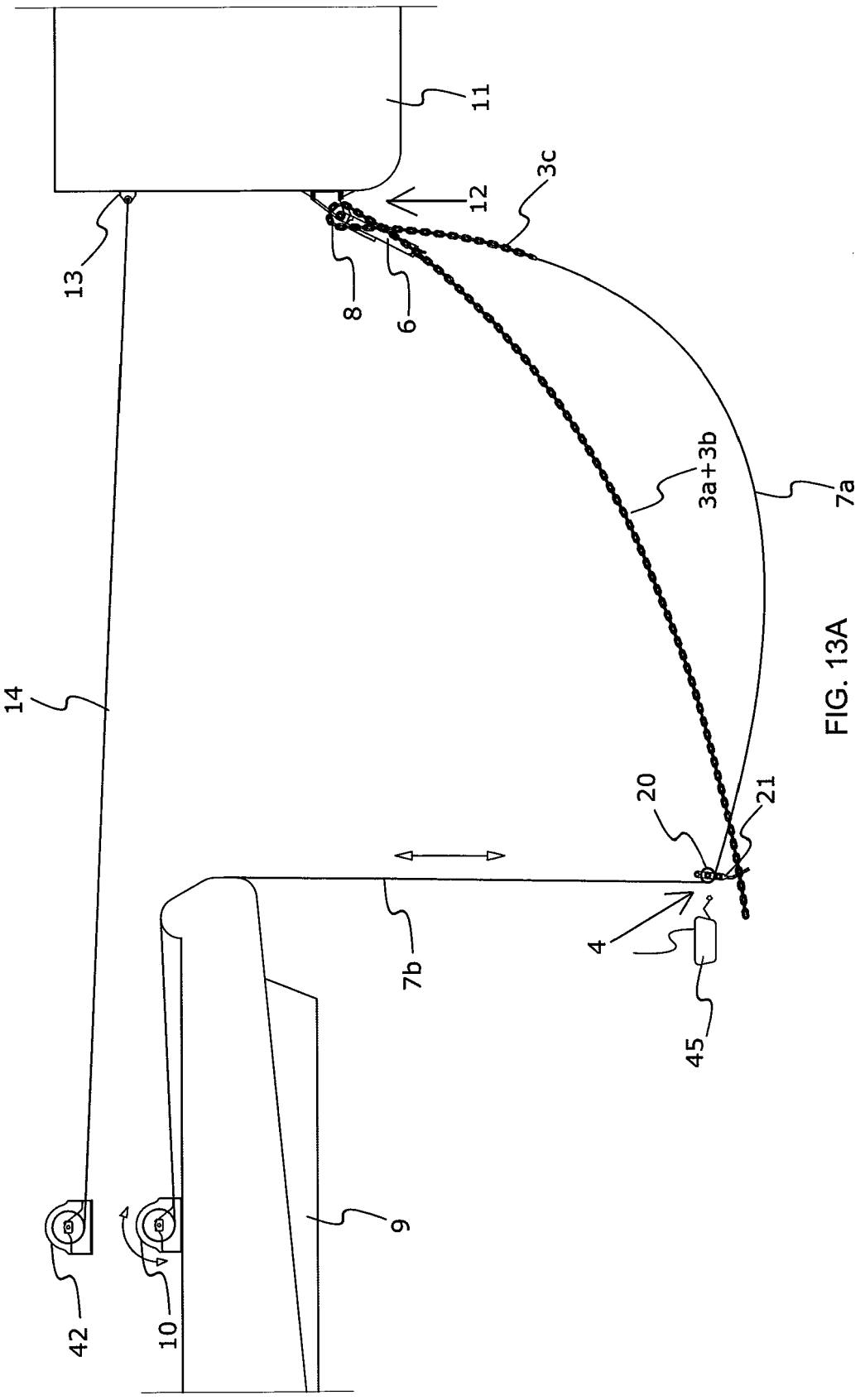


FIG. 13A

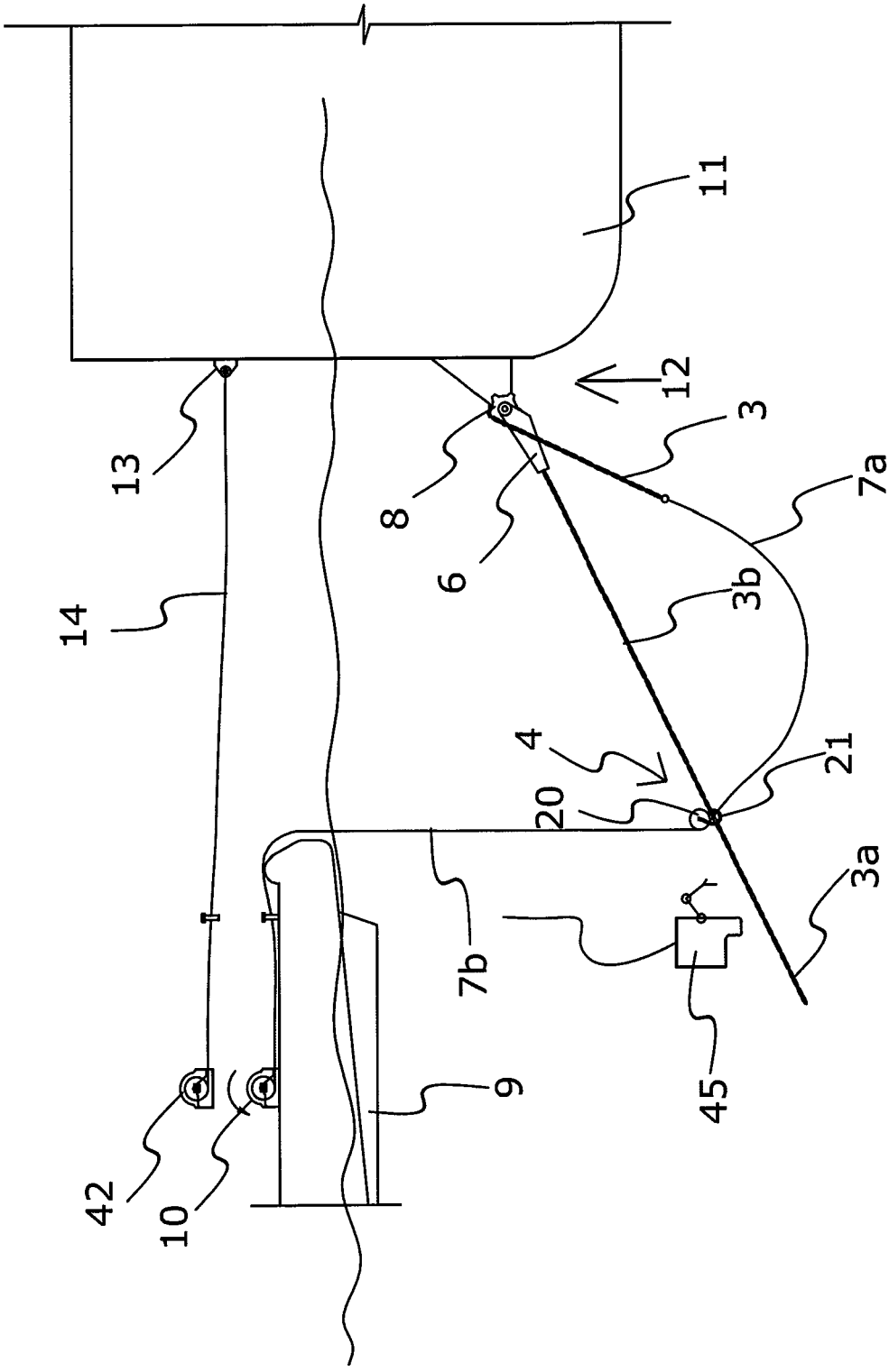


FIG. 13B

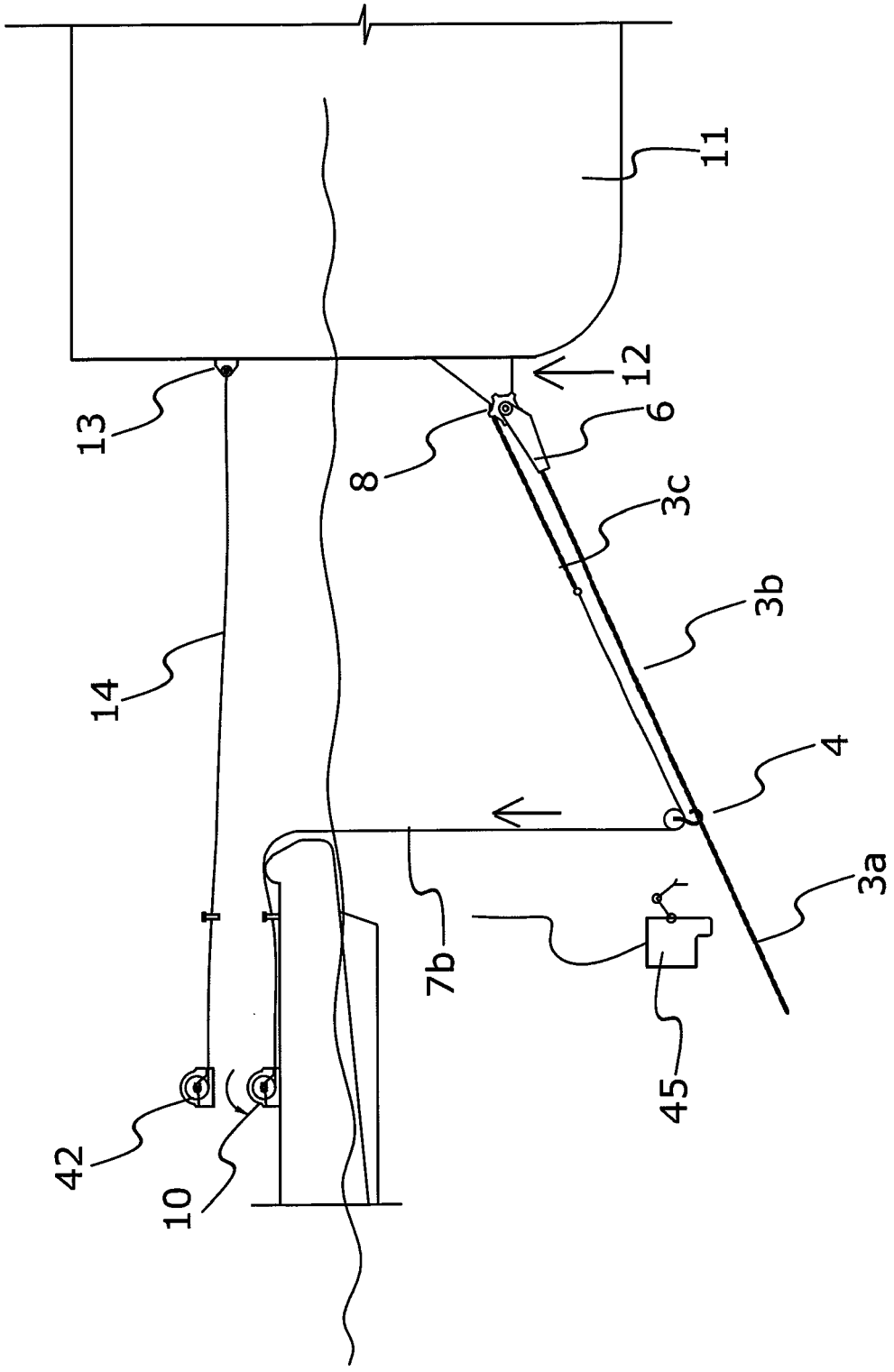


FIG. 13C

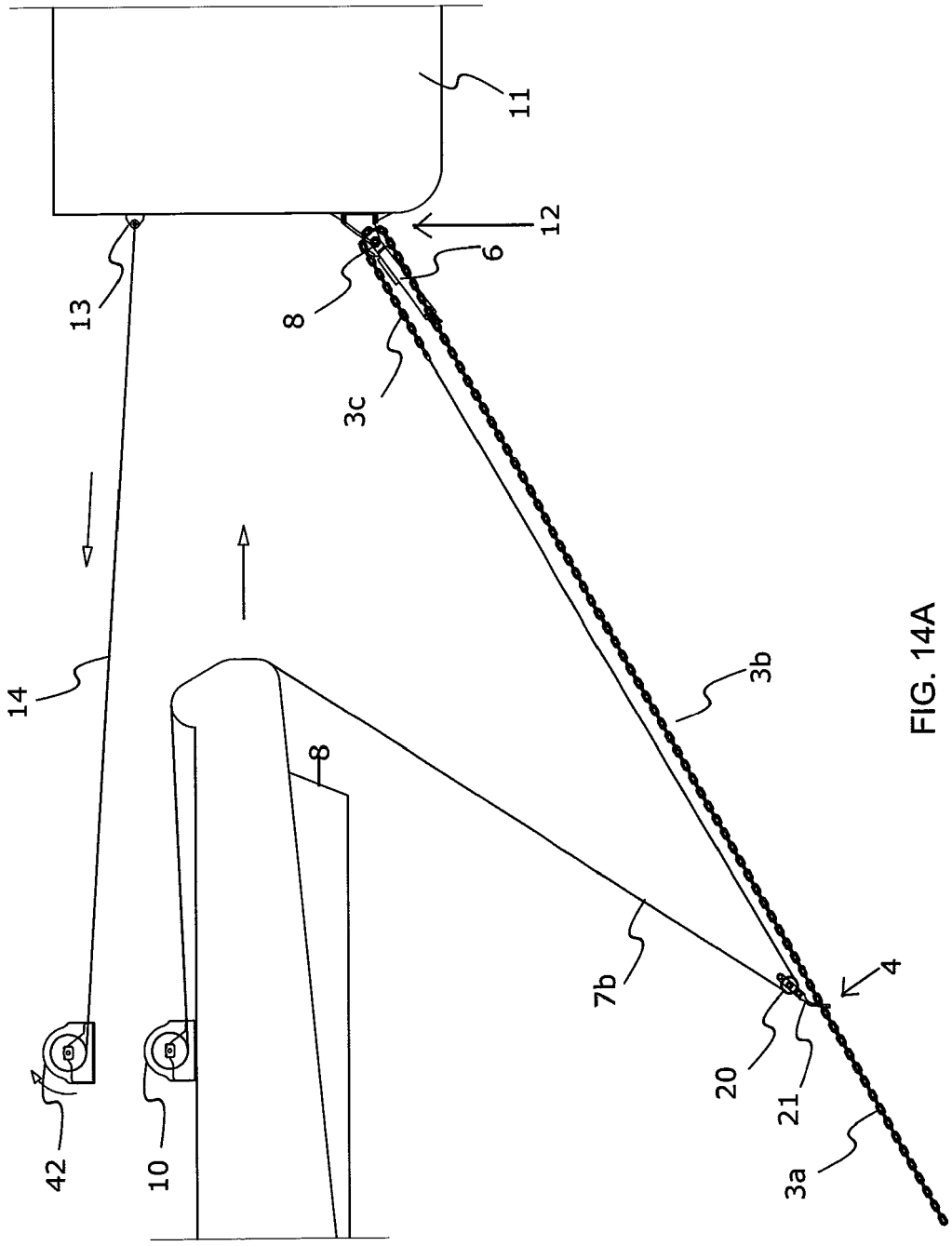


FIG. 14A

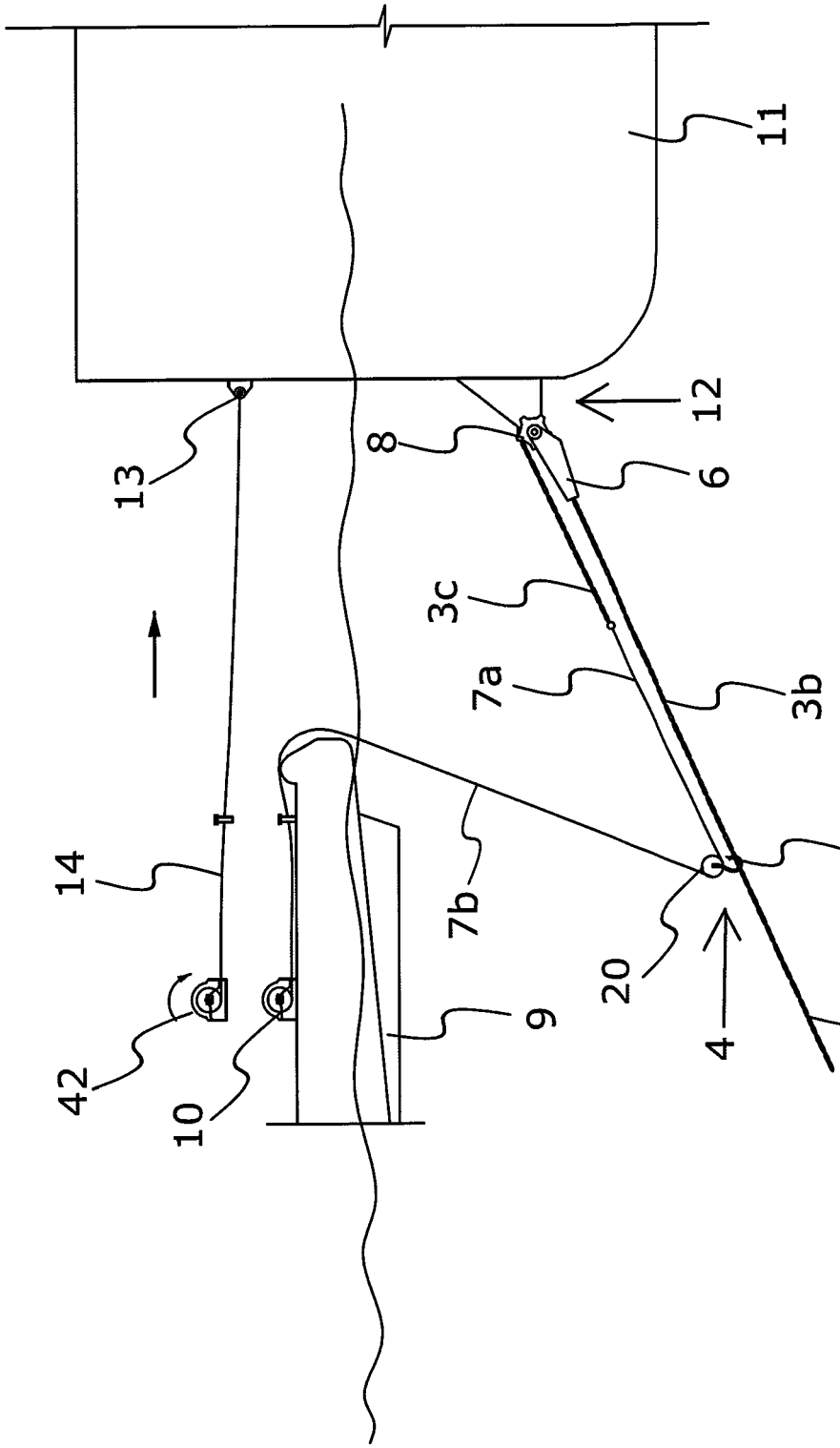


FIG. 14B

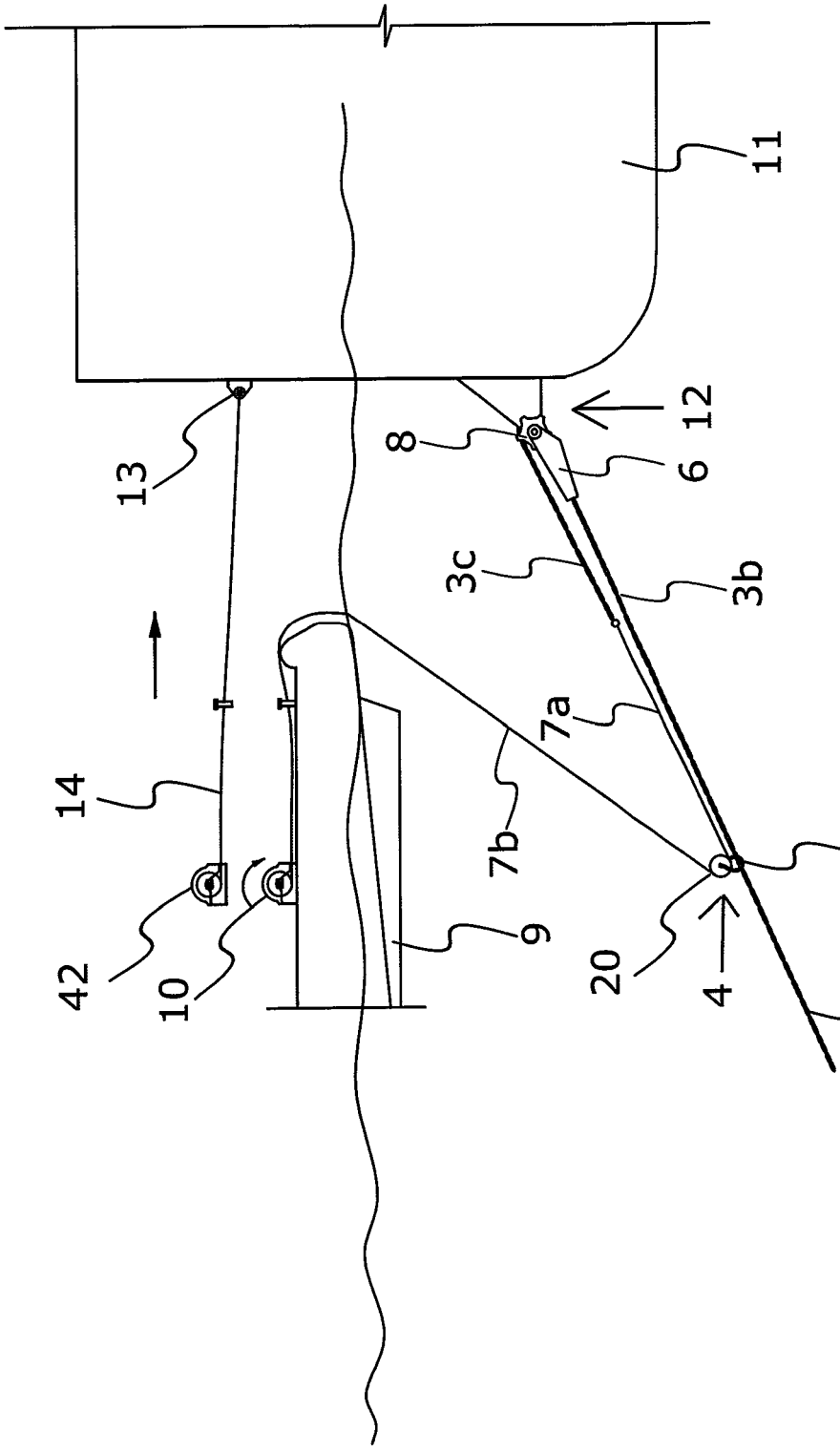


FIG. 14C

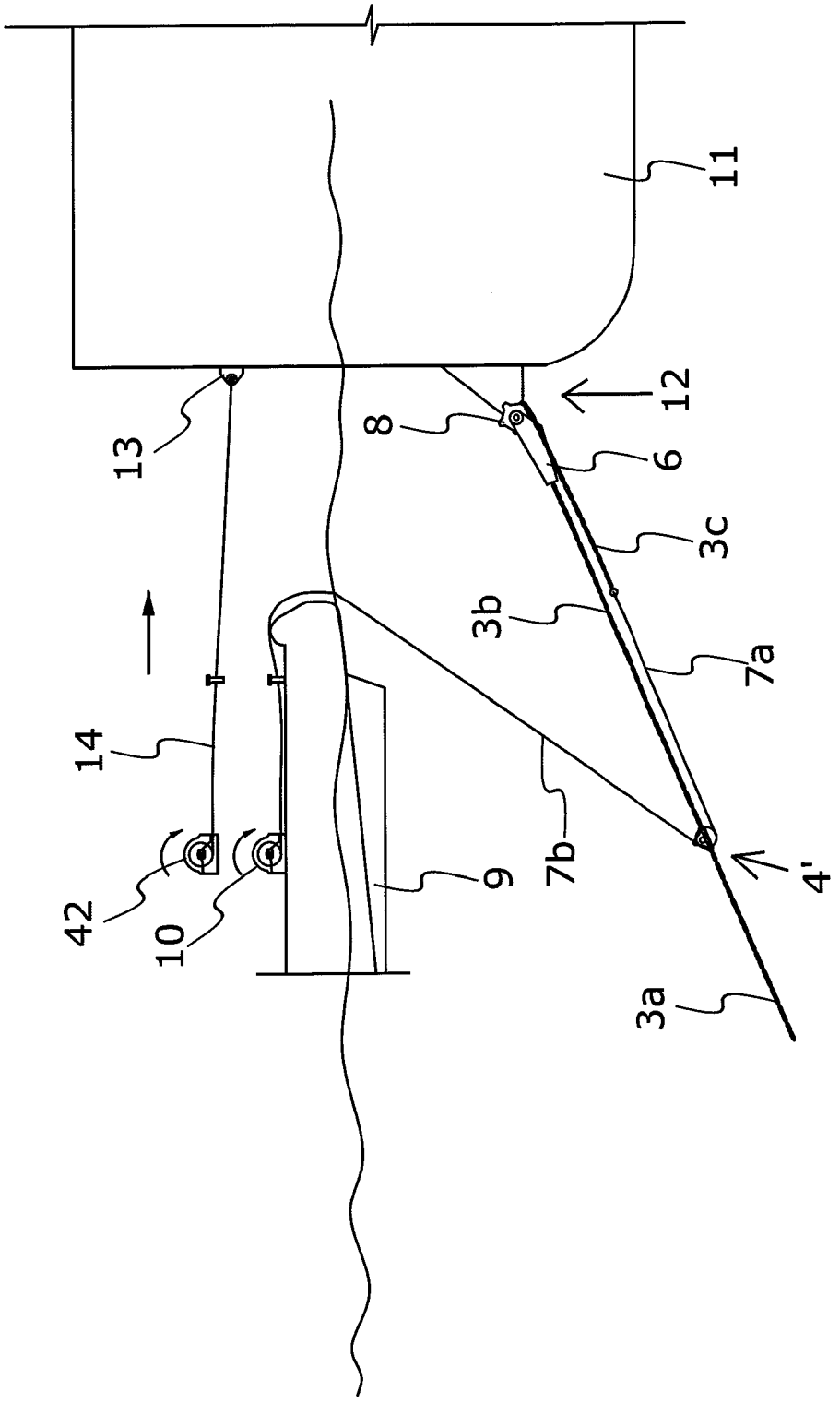


FIG. 14D

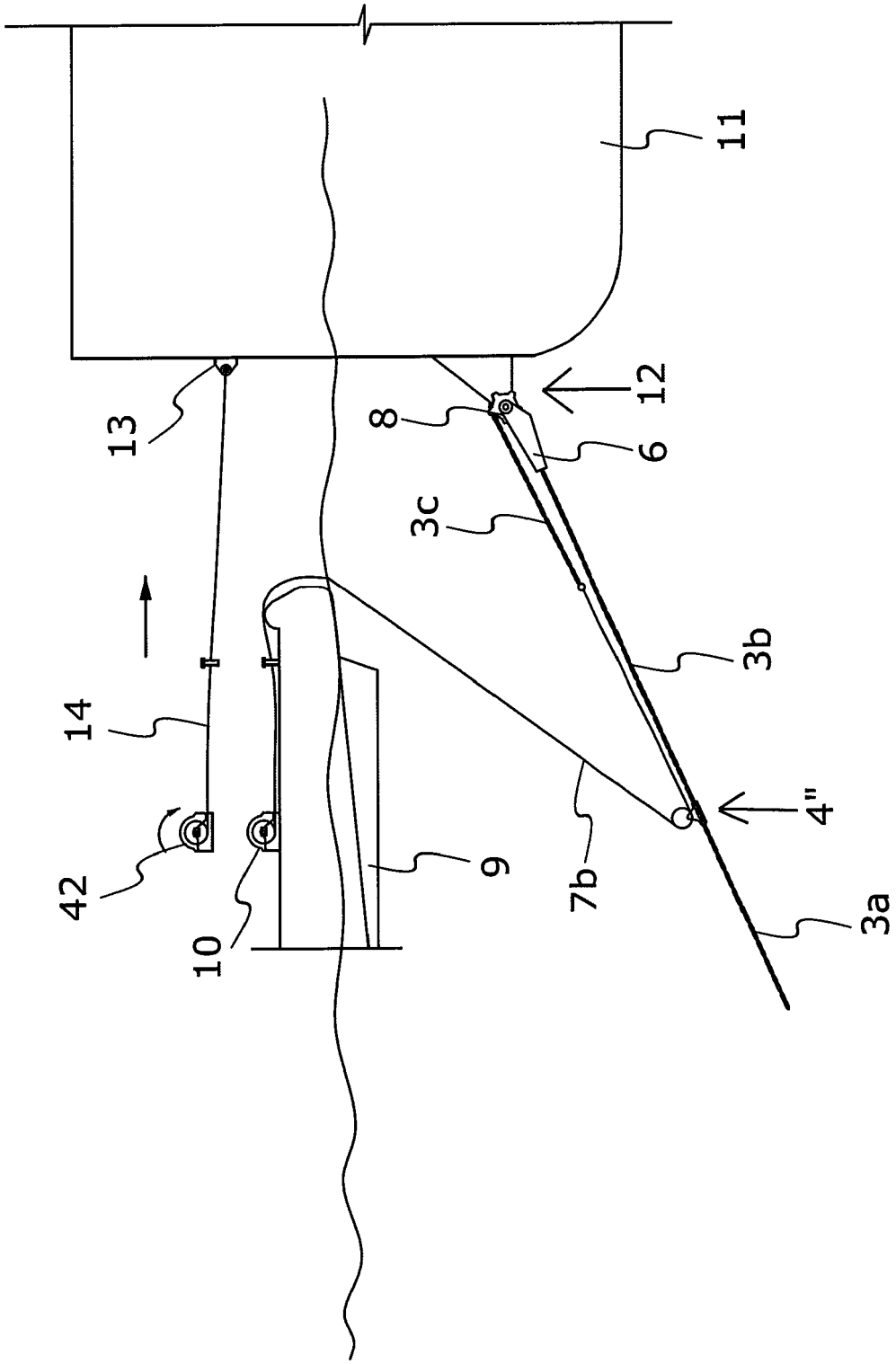


FIG. 14E

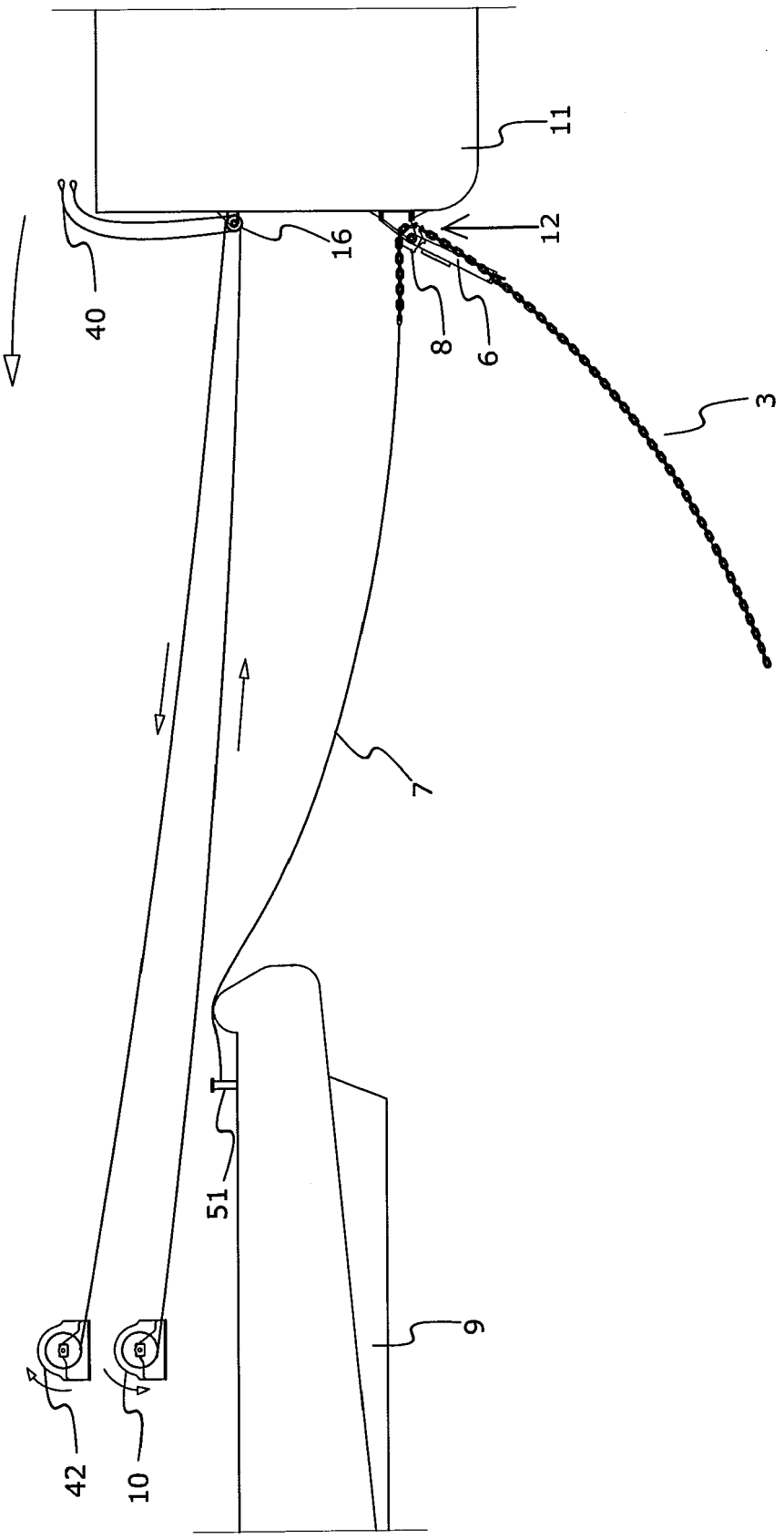


FIG. 15

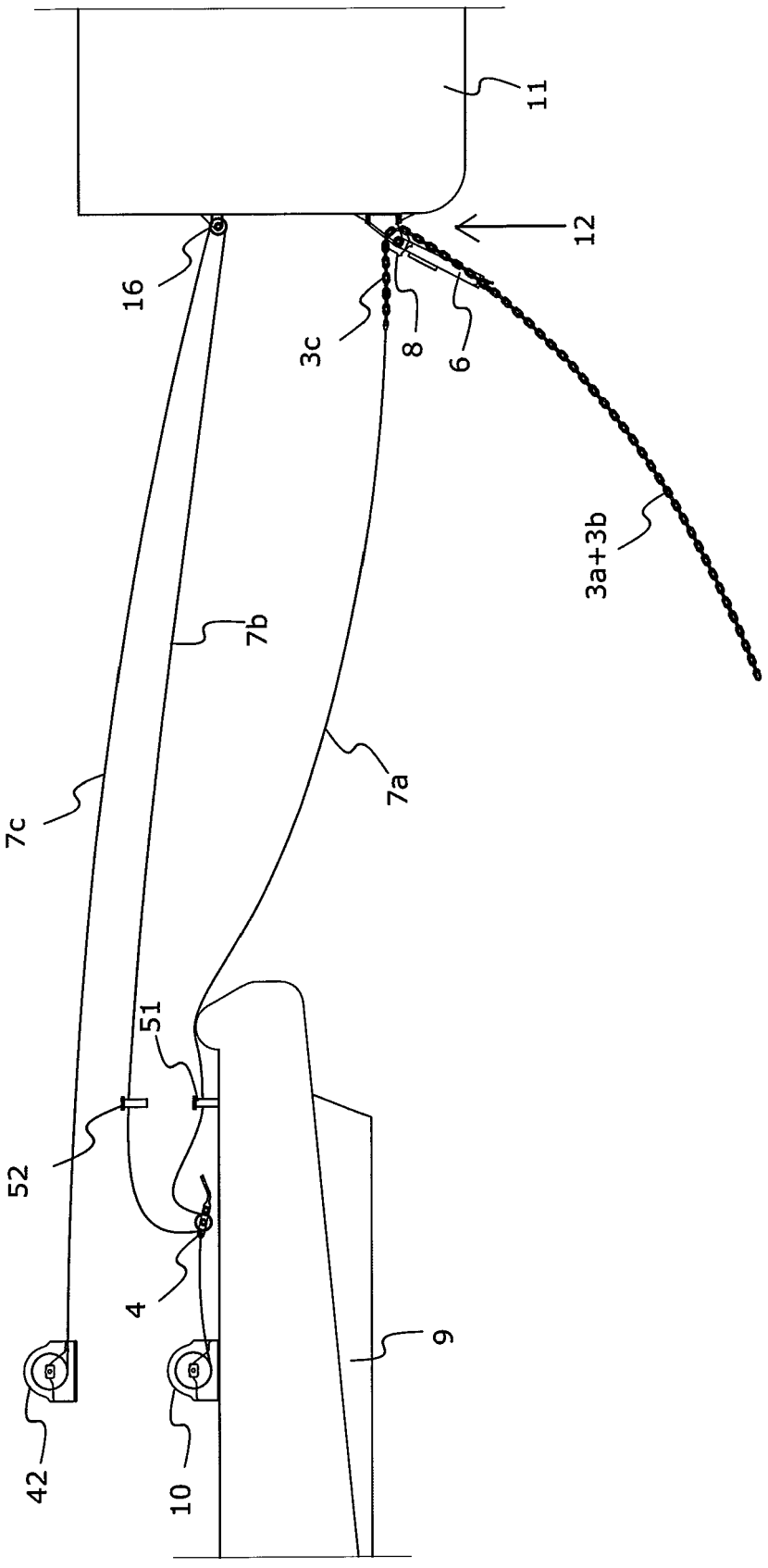


FIG. 16A

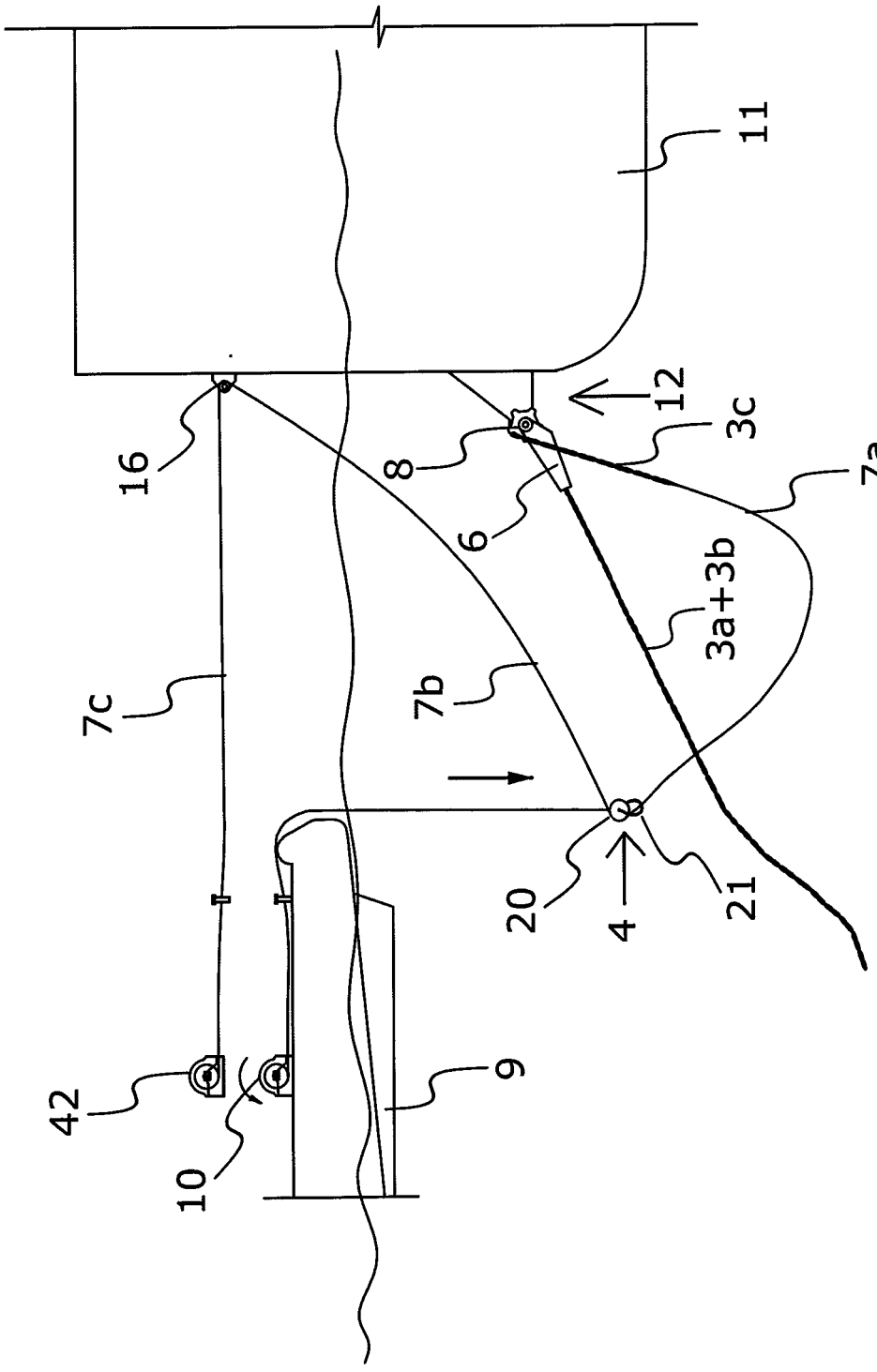


FIG. 16B

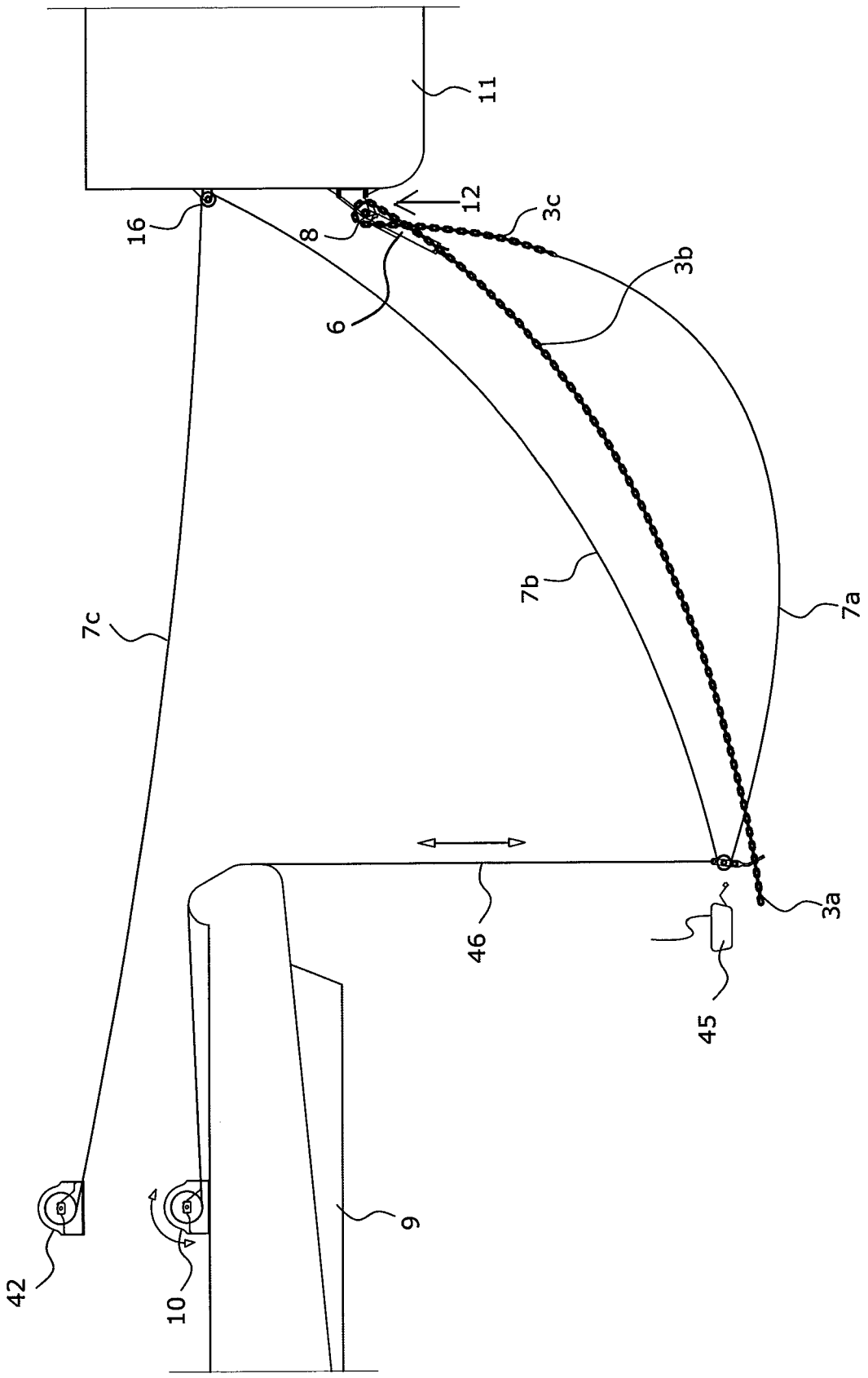


FIG. 16C

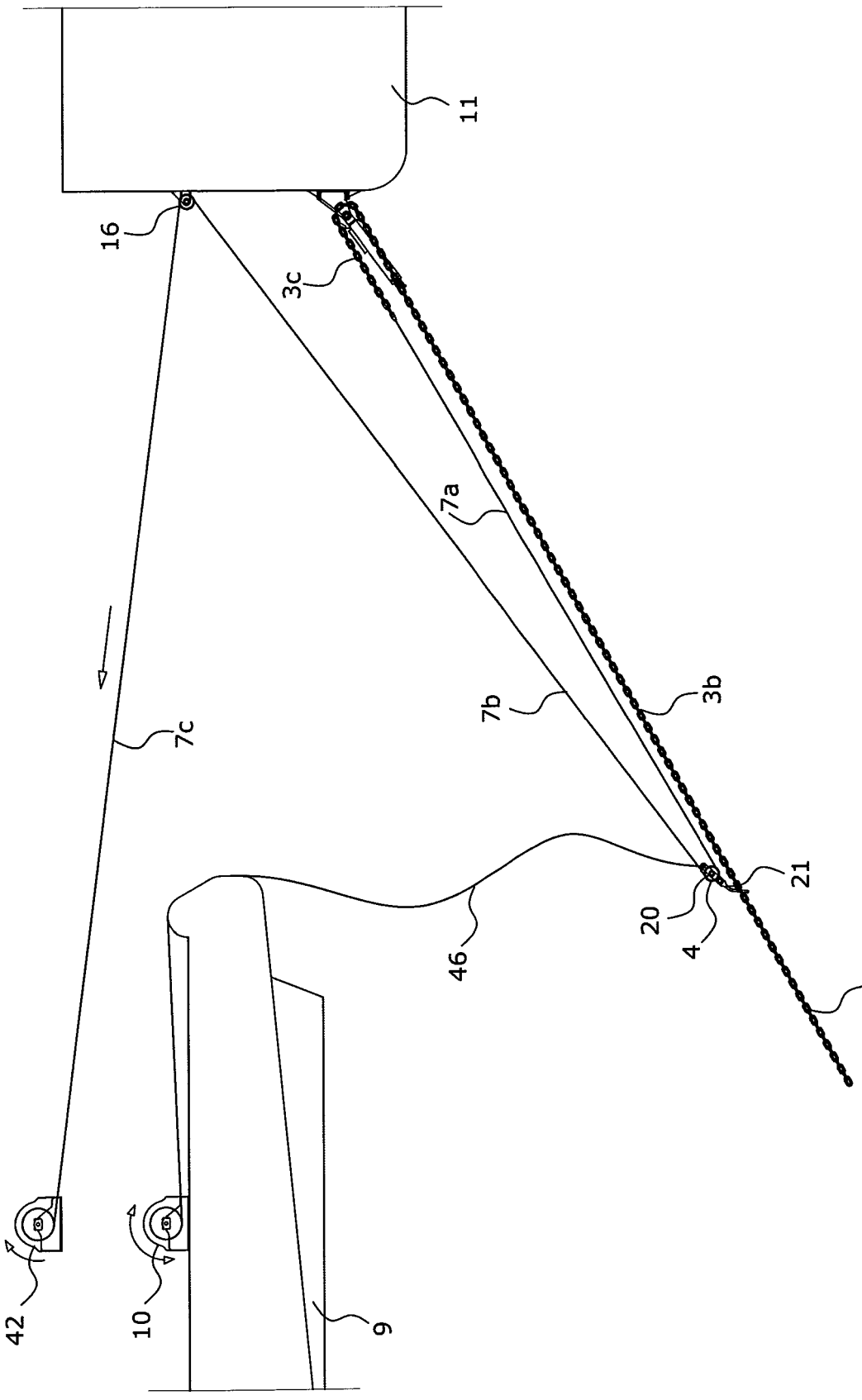


FIG. 17

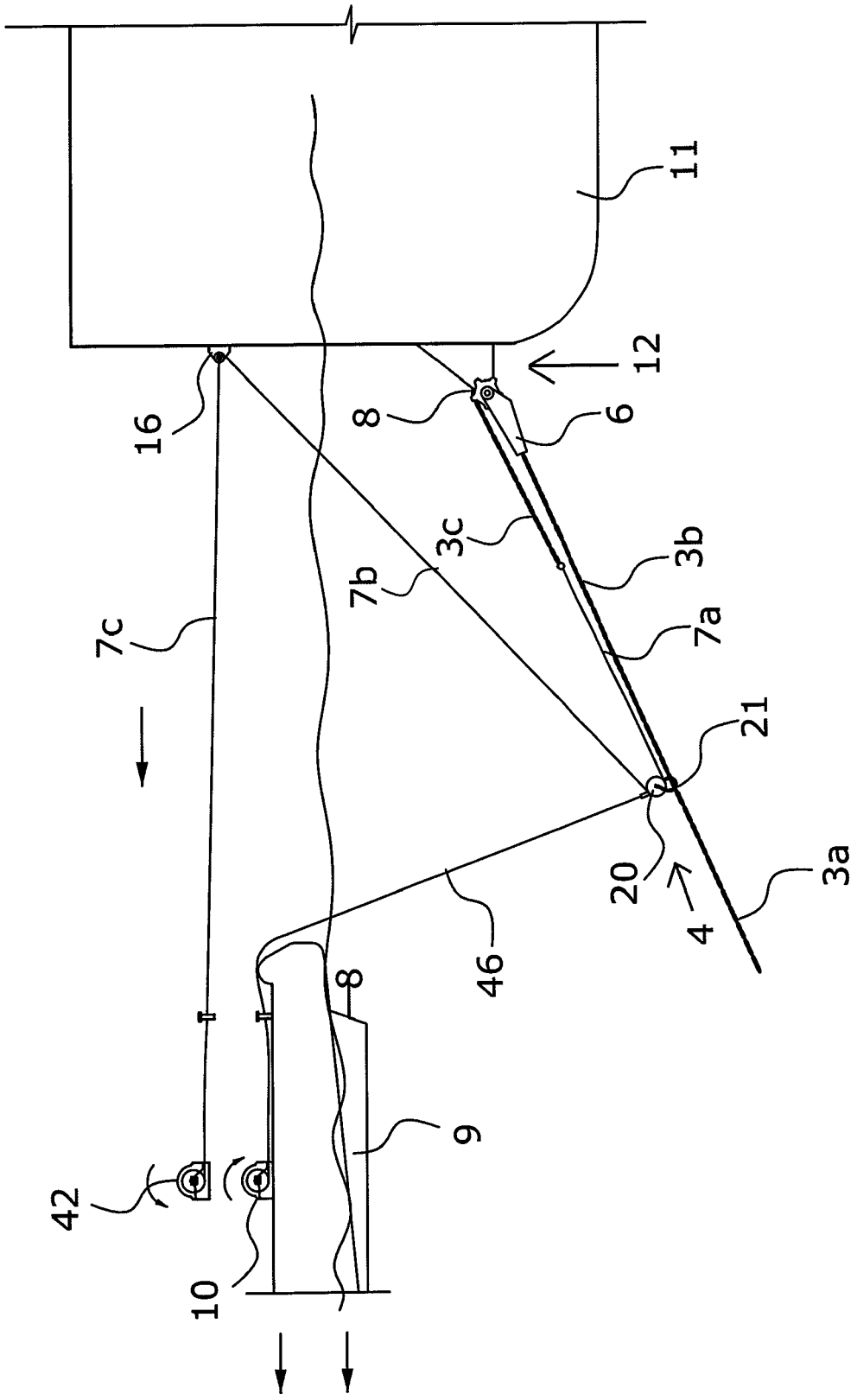


FIG. 18A

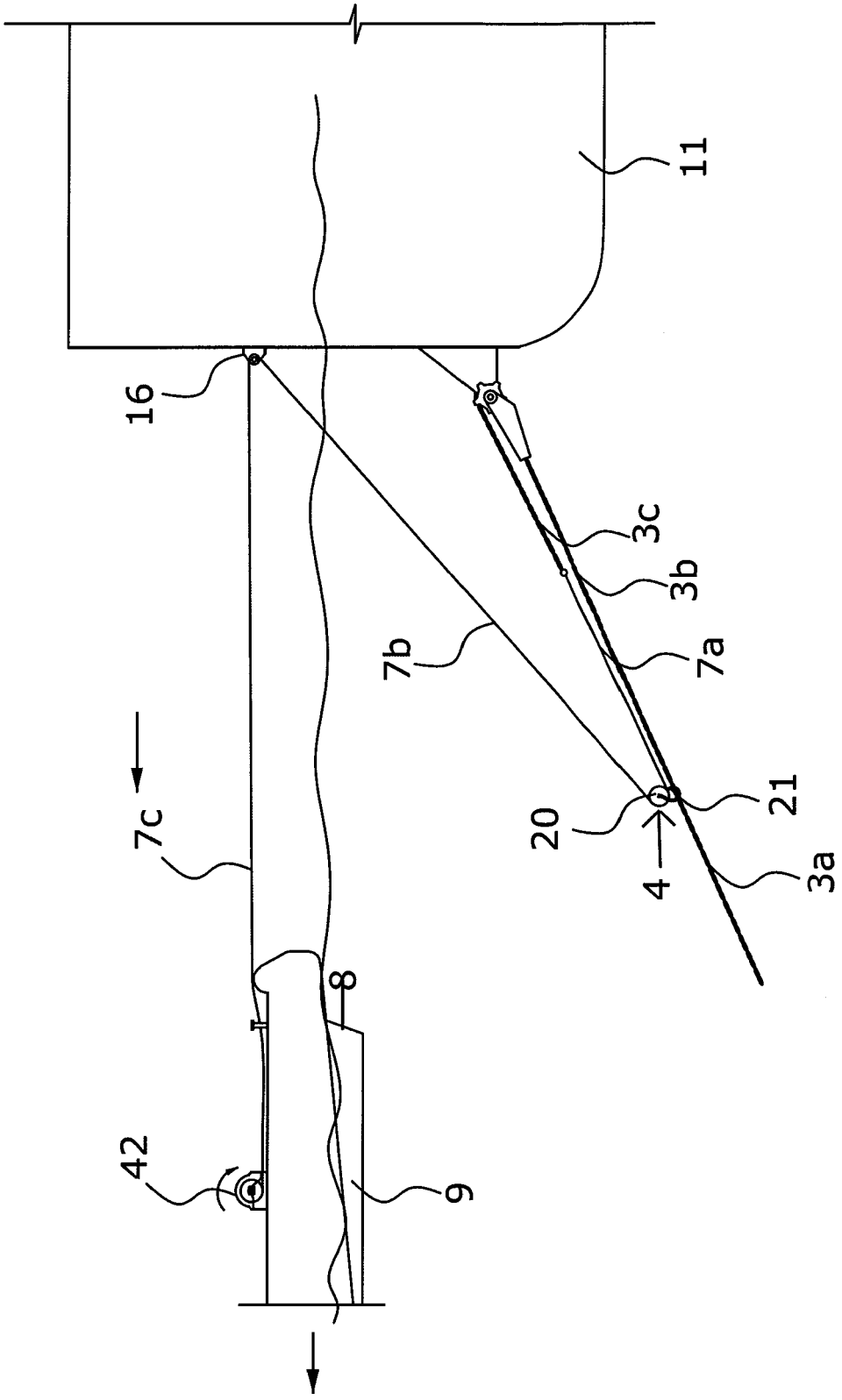


FIG. 18B

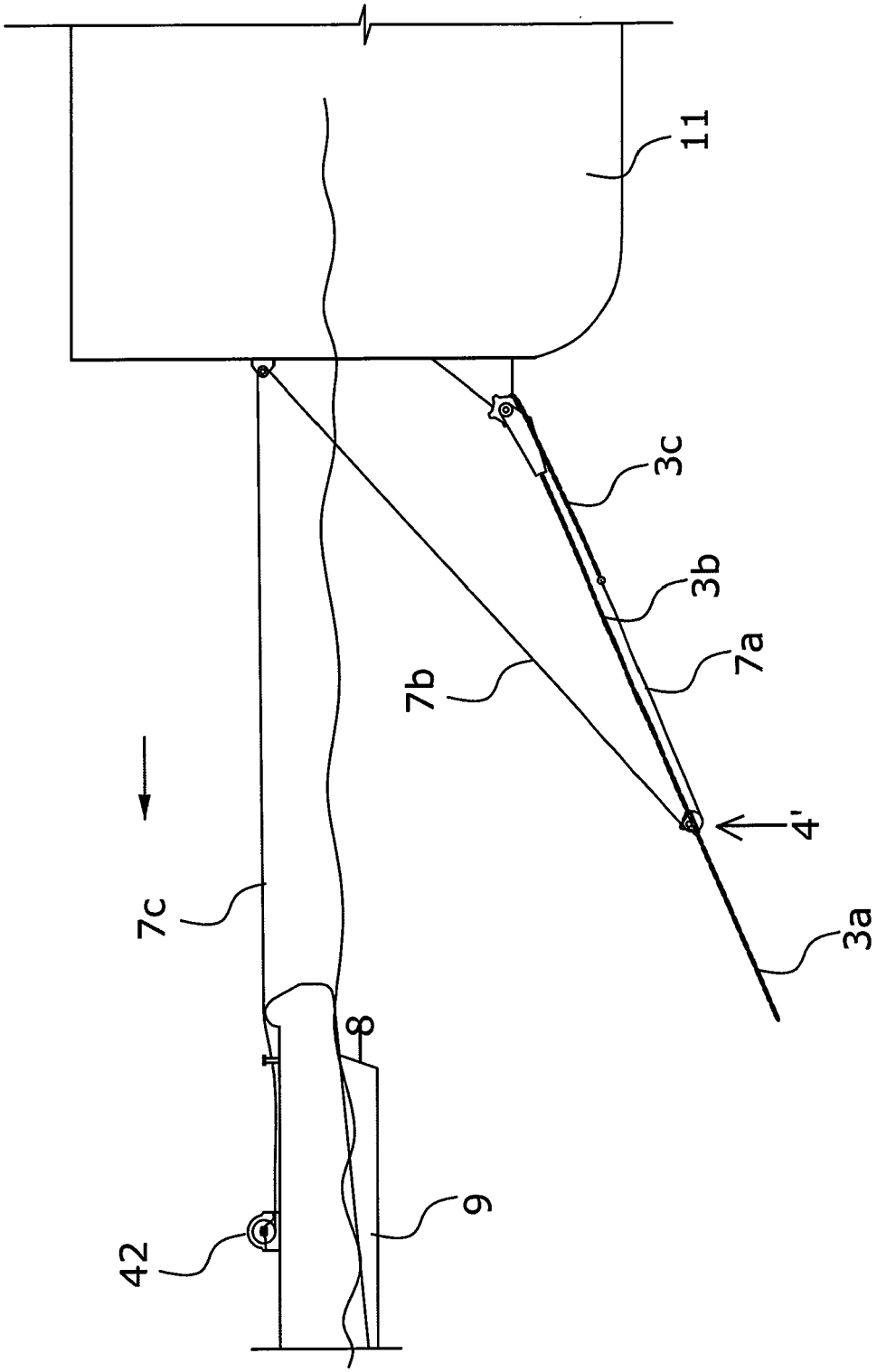


FIG. 18C

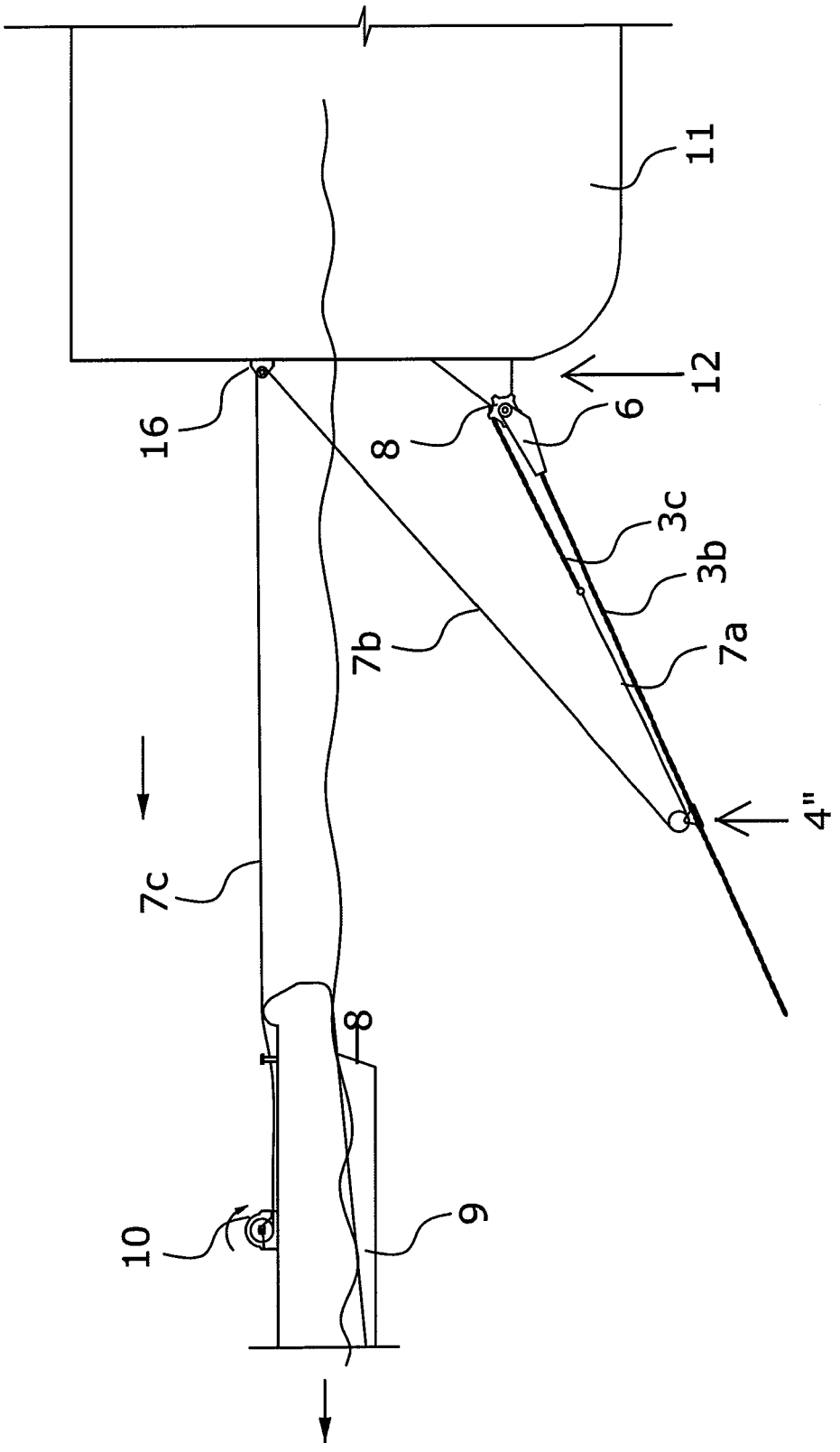


FIG. 18D

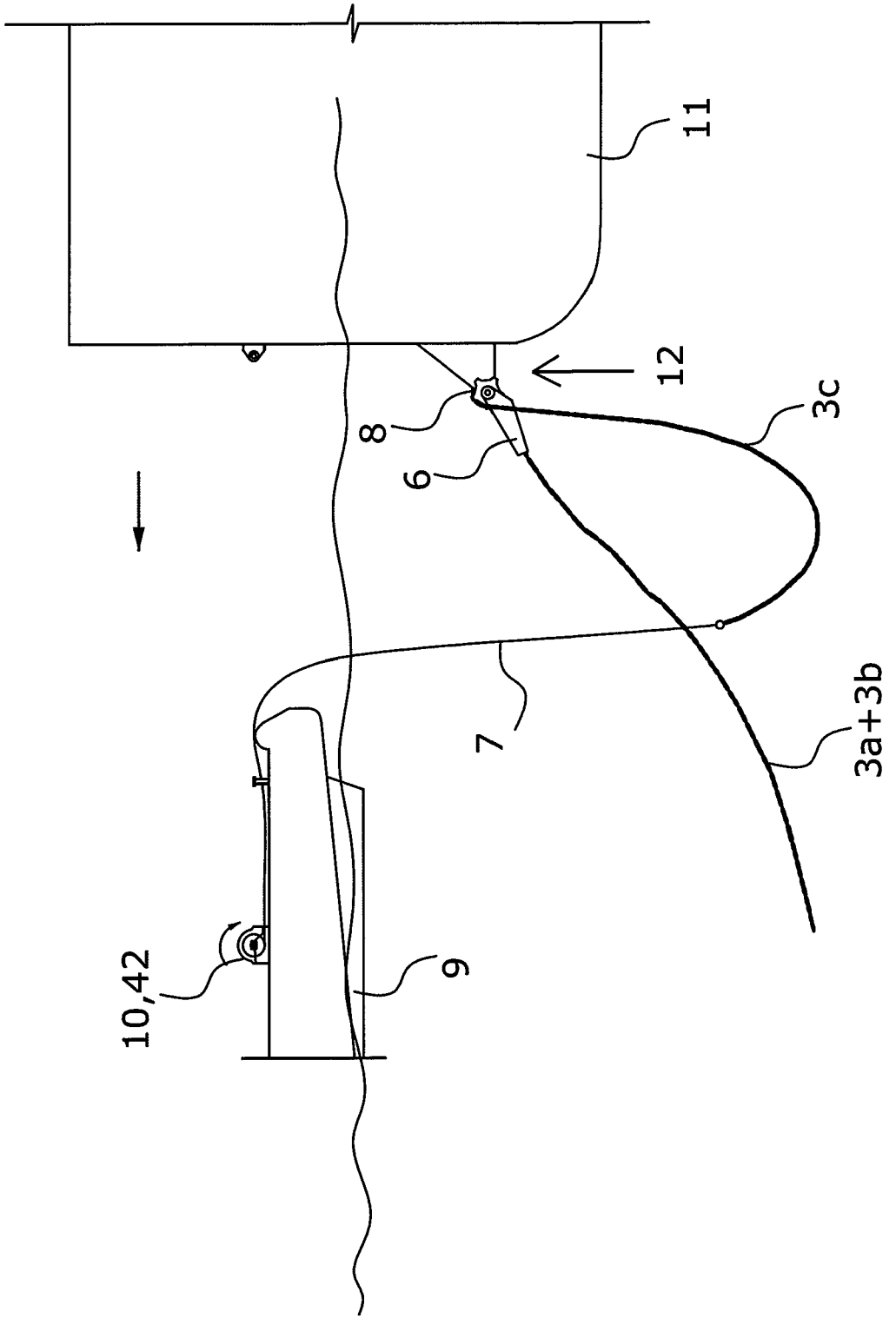


FIG. 19

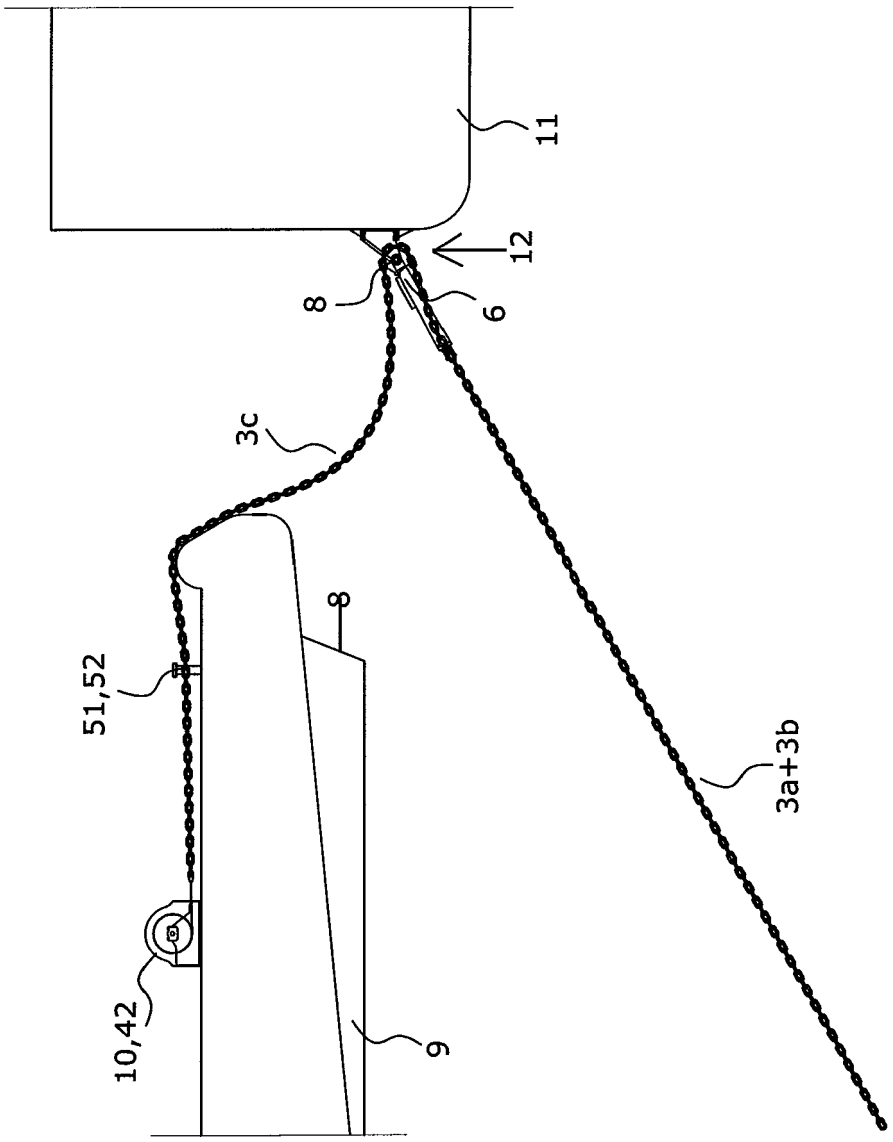


FIG. 20

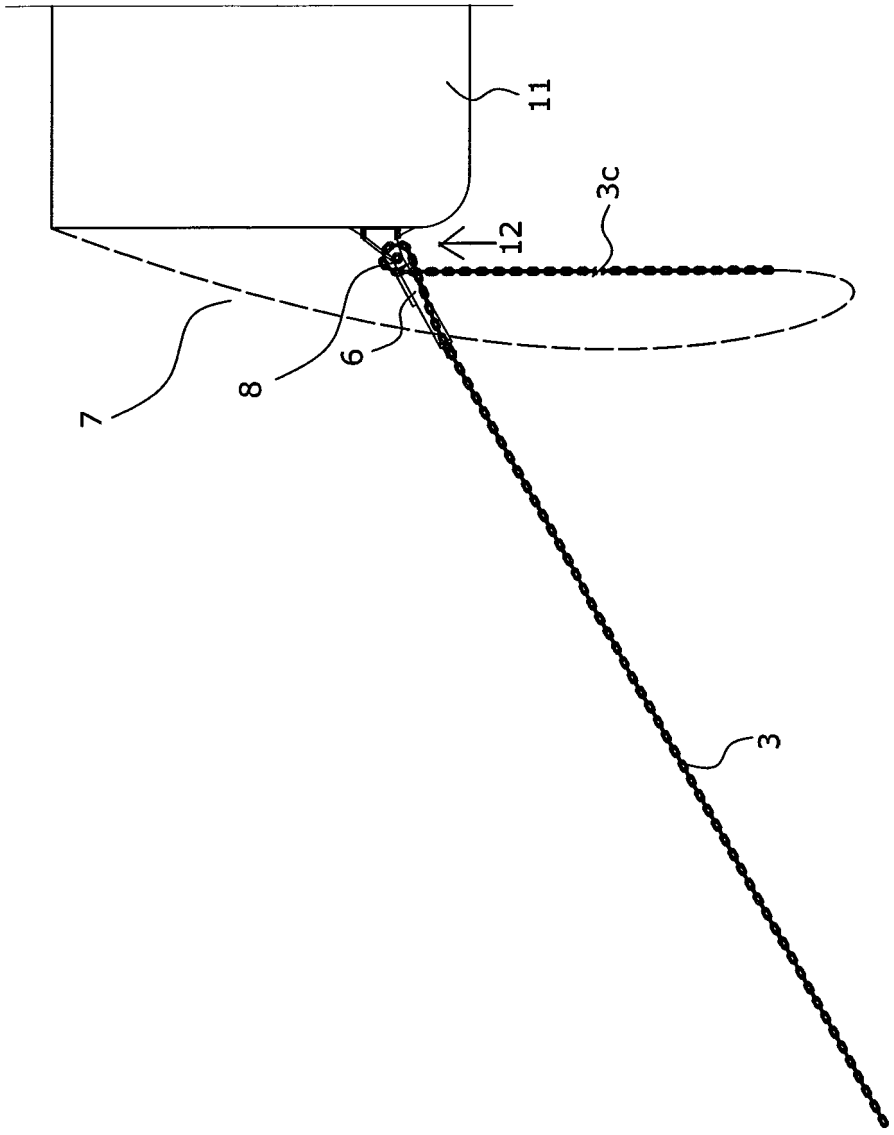


FIG. 21

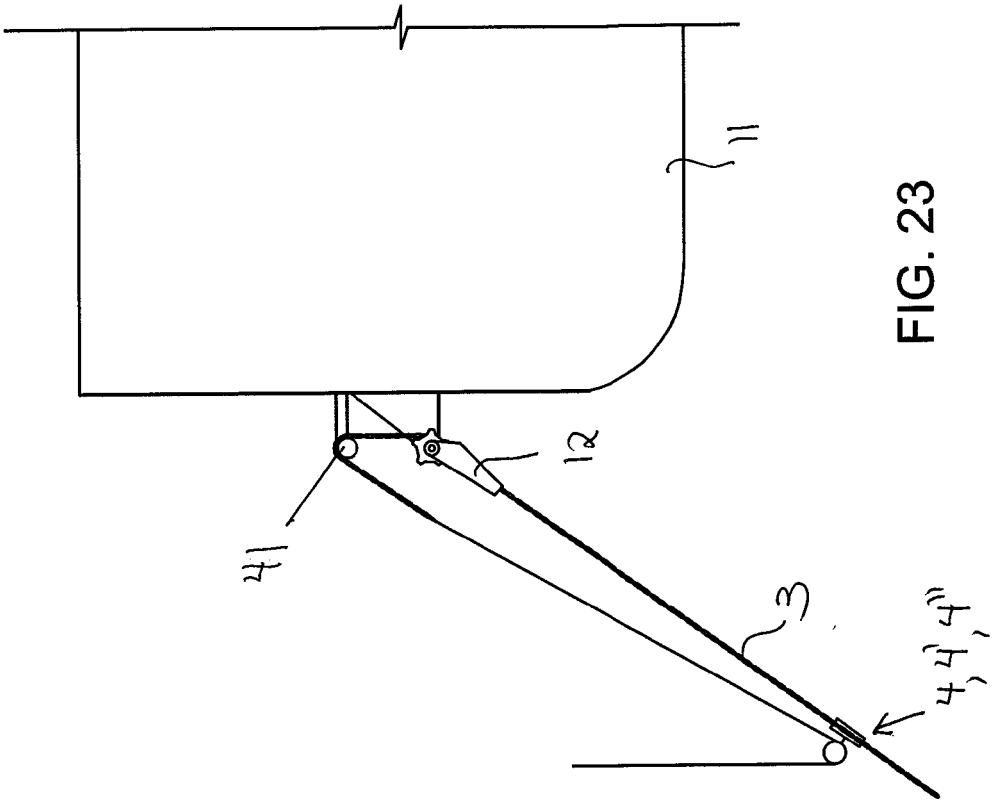


FIG. 23

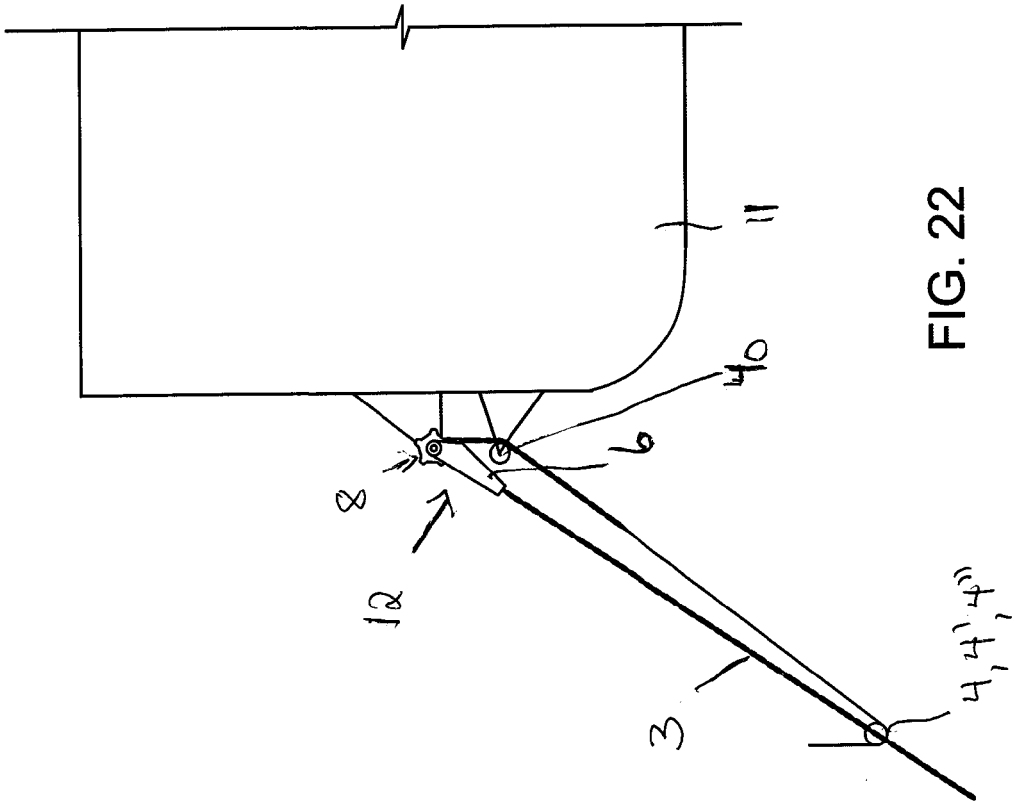


FIG. 22

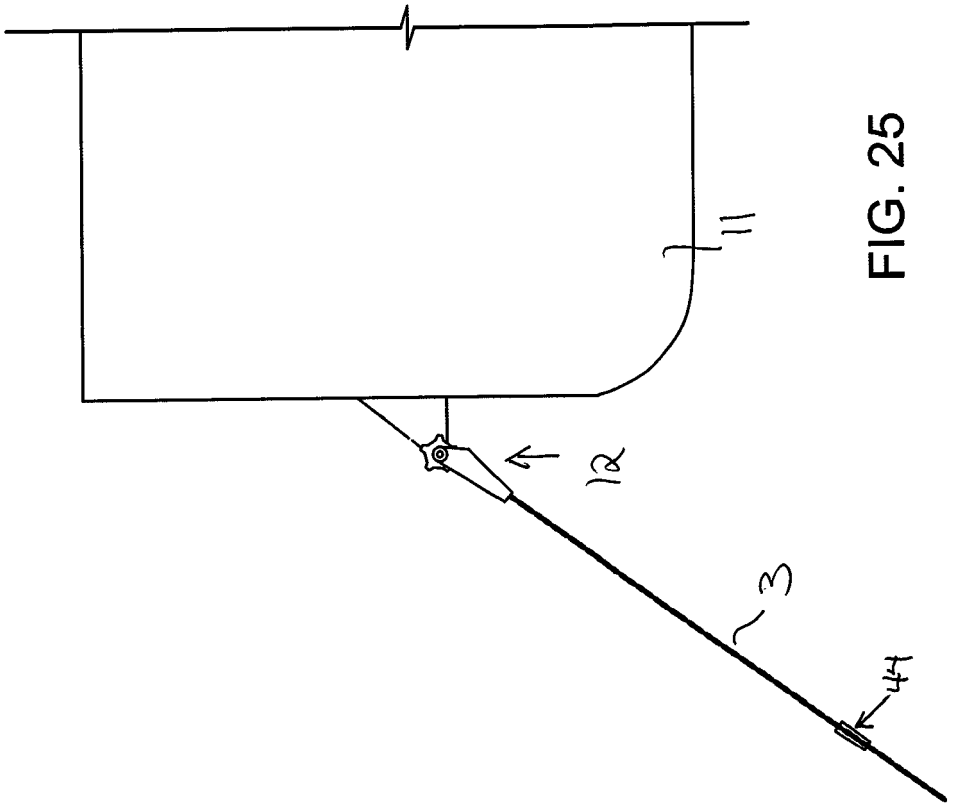


FIG. 25

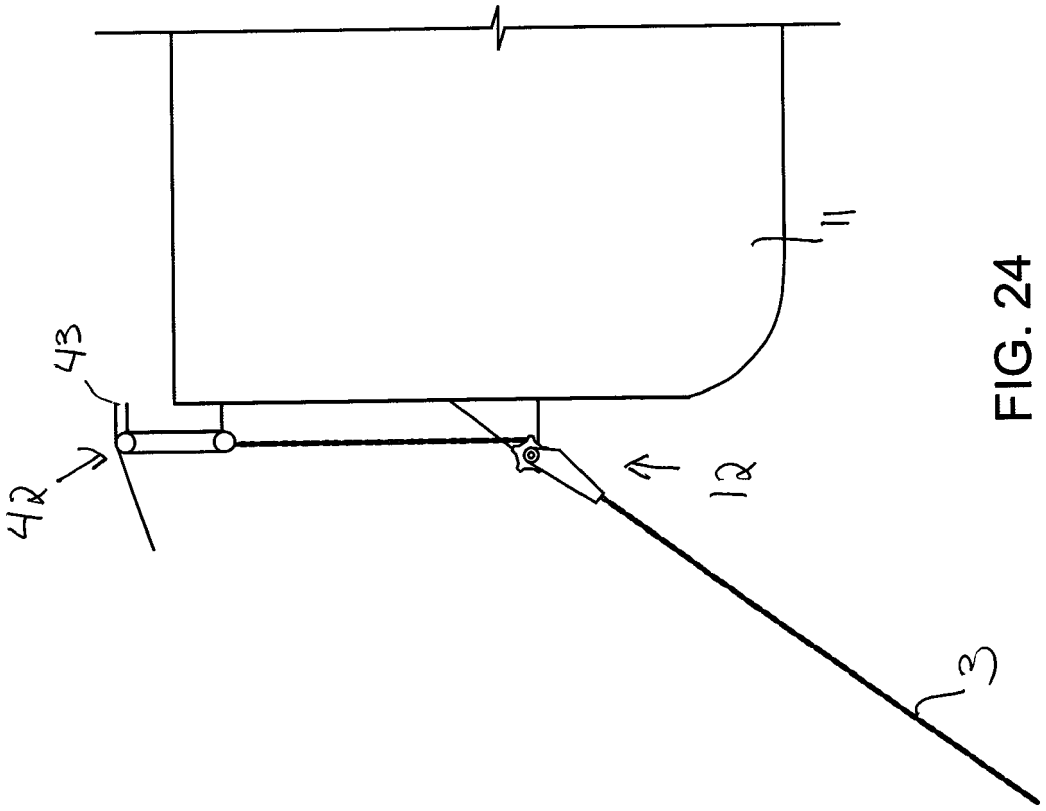


FIG. 24

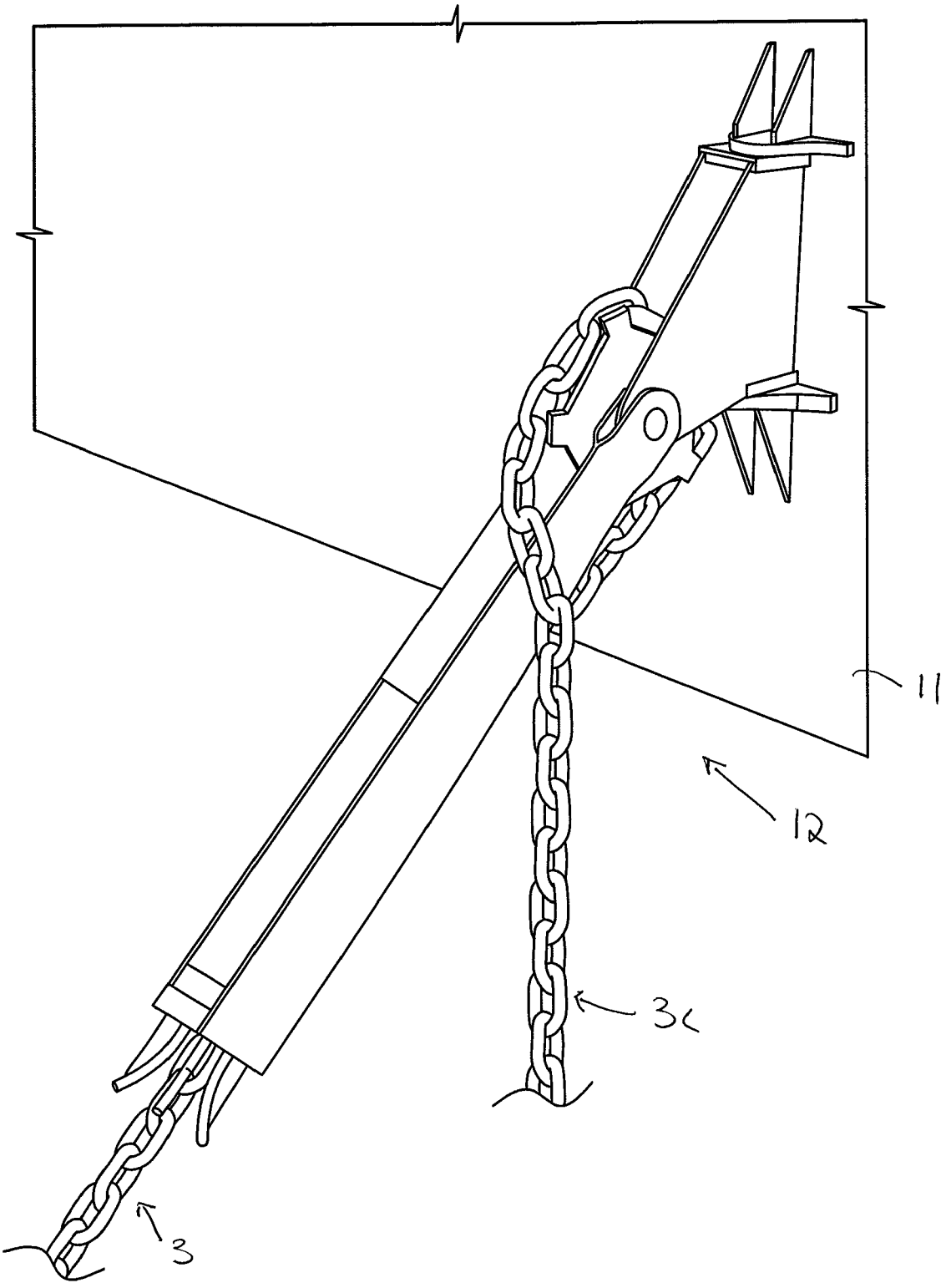


FIG. 26

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EUROPEAN SEARCH REPORT

Application Number
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	29 September 2017	Popescu, Alexandru

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