(12) **APPLICATION**

(11) **20220645** (13) **A1**

**NORWAY**

(19) NO

(51) Int Cl.

***E21B 33/064 (2006.01)***
***E21B 41/00 (2006.01)***
***E21B 41/08 (2006.01)***

## Norwegian Industrial Property Office


| | | | | | |
|---|---|---|---|---|---|
| (21) | Application nr | 20220645 | (86) | Int. application day and application nr | 2020.11.06 PCT/NO2020/050273 |
| (22) | Application day | 2022.06.03 | (85) | Entry into national phase | 2022.06.03 |
| (24) | Date from which the industrial right has effect | 2020.11.06 | (30) | Priority | 2019.11.07, GB, 1916201<br>2019.11.07, GB, 1916204<br>2019.11.07, GB, 1916206<br>2019.11.07, GB, 1916208 |
| (41) | Available to the public | 2022.06.03 | | | |

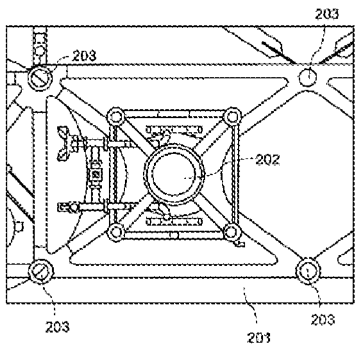


| | | |
|---|---|---|
| (71) | Applicant | AKER SOLUTIONS AS, Postboks 94, 1325 LYSAKER, Norge |
| (72) | Inventor | Brynjulf Spalder, Villaveien 20 H, 1385 ASKER, Norge<br>Rolf Barfod Schüller, Tranga 7, 1440 DRØBAK, Norge<br>Martin Pedersen, Lilloe-Olsens vei 17 B, 0489 OSLO, Norge<br>Martin Helgen, Trulsrudskogen 100, 1350 LOMMEDALEN, Norge |
| (74) | Agent or Attorney | ZACCO NORWAY AS, Postboks 488, 0213 OSLO, Norge |


(54) Title **SUBSEA WELLHEAD SYSTEMS AND METHODS**

(57) Abstract


A subsea wellhead assembly (300) comprising a well frame (301) arranged on a sea floor (398) and supporting a wellhead (302), a blow out preventer (305) arranged on the wellhead (302), a plurality of anchors (399) disposed on and secured to the sea floor about the well frame (301), wherein a plurality of tension members (304) arranged between the plurality of anchors (399) and the blow out preventer (305).

# SUBSEA WELLHEAD SYSTEMS AND METHODS

The present invention relates to subsea wellhead systems and methods, and particularly to such systems and methods for enhanced load transfer between components of a subsea wellhead system for the purpose of wellhead load relief.

## BACKGROUND

Wellhead systems for subsea petroleum exploration are traditionally known to comprise a wellhead having a wellhead housing secured to a well casing. It also generally has a valve stack, such as a blow out preventer (hereinafter referred to as BOP) or valve tree, located permanently or temporarily on the wellhead, for example during drilling, work-over operations and various phases of the production.

When a riser is connected to the valve stack, in some cases high bending moments and/or cyclic forces may be applied on the valve stack from the riser. These forces and moments may then be led onto the wellhead structure. As a result, the wellhead and associated components may be exposed to loads (of a one-off, intermittent and/or cyclic nature) which can cause damage or fatigue and lead to reduced operational lifetime or increasing the risk of component failure.

Publications which may be useful to understand the background include WO 2012/065896; WO 2014/210026; WO 2016/118019; EP 3 102 771 B1 and WO 2019/103625 A1.

Due to the potentially serious consequences of such damage or fatigue in these safety-critical components, there is a continuous need for improved technology for wellhead systems which may be exposed to such forces or loads, for example from a BOP or subsea riser. The present disclosure has the objective to provide such improvements, or at least alternatives to known solutions and techniques.

## SUMMARY

In an embodiment, there is provided a subsea wellhead assembly comprising a well frame arranged on a sea floor and supporting a wellhead, a blow out preventer arranged on the wellhead, a plurality of anchors disposed on and secured to the sea floor about the well frame, wherein a plurality of tension members arranged between the plurality of anchors and the blow out preventer.

Various further embodiments are outlined in the detailed description and claims below, and in the appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other characteristics will become clear from the following description of illustrative embodiments, given as non-restrictive examples, with reference to the attached drawings, in which:

Fig. 1 is a perspective view of parts of a subsea wellhead assembly.

Fig. 2 is a schematic view of a subsea wellhead assembly.

Fig. 3 is another view of the wellhead assembly of Fig. 2.

Fig. 4 is an illustration of certain aspects of the wellhead assembly.

Fig. 5 is a perspective view of a wellhead assembly in another embodiment.

Figs 6-8 are different views of a wellhead assembly in another embodiment.

Figs 9 and 10 are different views of a wellhead assembly in another embodiment.

Figs 11 and 12 show aspects of tensioning members for use with embodiments described herein.

Fig. 13 shows a blow out preventer according to an embodiment.

Fig. 14 shows a blow out preventer according to an embodiment.

Fig. 15 shows a blow out preventer according to an embodiment.

Figs 16-21 illustrate embodiments of a wellhead assembly having a suction anchor well foundation.

Figs 22-28 illustrate embodiments of a wellhead assembly having a support frame for supporting a blow out preventer.

Figs 29-35 illustrate further embodiments of a wellhead assembly having a support frame for supporting a blow out preventer.

Fig. 36 shows a top view of a well frame and wellhead according to some embodiments.

Fig. 37 illustrates a subsea wellhead assembly according to an embodiment.

Fig. 38 and 39 show an anchor according to an embodiment.

## DETAILED DESCRIPTION

The following description may use terms such as “horizontal”, “vertical”, “lateral”, “back and forth”, “up and down”, ”upper”, “lower”, “inner”, “outer”, “forward”, “rear”, etc. These terms generally refer to the views and orientations as shown in the drawings and that are associated with a normal use of the invention. The terms are used for the reader’s convenience only and shall not be limiting.

Fig. 1 shows a subsea wellhead assembly 100 having a well frame 101 supporting at least one wellhead 102. The well frame 101 can be a template or a different type of frame structure which supports the wellhead 102. As will be clear from the below description, different embodiments may have different number of wellheads 102 supported by the frame 101, for example one, two or four wellheads 102. Figure 1 illustrates parts of a four-wellhead frame, where two wellheads are visible in the view shown.

Figures 2 and 3 illustrate a side view of a wellhead assembly 100 as shown in Fig. 1.

The well frame 101 is supported on a sea floor 127 (see Fig. 2) by a plurality of suction anchors 110, in this case four suction anchors 110. As will be described below, other embodiments may include a single suction anchor for support, or a different type of foundation towards the sea floor 127.

The well frame 101 has a plurality of connection points 103 arranged in the well frame 101 and disposed about the at least one wellhead 102. The connection points 103 are configured for holding a tension member 104 fixed to the frame 101. In any of the embodiments described herein, the connection points 103 can be any type of connection means or fixation arrangement. For example, the connection points can be similar as or identical to connectors 203 described below.

When carrying out certain operations, such as drilling or well intervention, a blow out preventer 105 is arranged on the wellhead 102 (or one of the wellheads 102), as can be seen in Fig. 1. The blow out preventer 105 is conventionally suspended by a riser 117 (illustrated only schematically here) from a vessel, and landed on the frame 101.

During this operation, a plurality of tension members 104 are arranged between the frame 101 and the blow out preventer 105. Each tension member 104 is fixed in a connection point 103 and extends to the blow out preventer 105, where it is similarly fixed in a suitable connection point 106. By tensioning-up the tension members 104, better support for the blow out preventer 105 can be provided, in that at least parts of a side force (or moment) acting on the blow out preventer 105 (for example, due to drift-off of the vessel suspending the riser 117 or sea currents acting on the riser 117 or blow out preventer 105) will be taken up by the tension members 104. The tension members 104 provide a load path from the blow out preventer 105, via the tension members 104, to the frame 101 and therethrough to the foundation of the wellhead assembly 100, in this case suction anchors 110. Consequently, such side forces or moments will bypass the wellhead 102, which is thus less exposed to fatigue or damage from such forces or moments.

In the embodiments shown in Figs 1-3, the connection points 103 on the frame 101 are disposed in a plane which the at least one wellhead 102 intersects, i.e. at the same or a similar height as the wellhead(s) 102. This may be a single, substantially horizontal frame 101, or a lower part of a frame 101 or template structure which also has a part extending upwardly from the lower part, see for example Fig. 5 below.

The frame 101 may, as illustrated, for example comprise H-beams or similar structural elements providing a rigid and stable structure. The frame 101 rests on, and is rigidly fixed to, the foundation elements, in this case suction anchors 110.

The blow out preventer 105 may have a substantially rectangular horizontal cross-section and be provided with four connection points 106, one in each of four corners of the blow out preventer 105 body. The blow out preventer 105 may, however have a smaller or larger number of connection points 106, and these may, alternatively or additionally, be arranged at different locations on the blow out preventer 105, for example on a side of the blow out preventer 105.

Advantageously, as shown in the embodiment in Fig. 1, from each of the connection points 103 in the well frame 101 there can be arranged two (or more) tension members 104 which extend to different connection points 106 on the blow out preventer 105.

In the embodiment shown in Fig. 1, two tension members 104 extending from the same frame connection point 103 are fixed to diagonally opposite connection points 106 on the blow out preventer 105. The two tension members 104 may be fixed to connection points 106 on the blow out preventer 105 which are spaced between a closest and a farthermost connection point 106 on the blow out preventer 105. This can be seen from Fig. 1, where each tension member 104 extends not to the closest corner of the blow out preventer 105 but to one of the diagonally opposite corners farther away from the closest corner.

It may be advantageous to arrange the plurality of connection points 103 to be disposed symmetrically about the at least one wellhead 102.

By implementing one or more of these arrangement options, an improved load distribution in the tension members 104 can be obtained. This can give enhanced load relief properties for the wellhead assembly 100 in that pre-tensioning of the tension members 104 is made easier. It may, for example, also be advantageous to let all tension members 104 have the same length and structural properties (such as material stiffness). This can avoid problems associated with obtaining accurate pre-tensioning in systems having different length, angle, or other characteristics between the tension members 104, thereby increasing accuracy, installation time and risk of incorrect pre-tensioning settings. These options, individually or combined, may also allow the connection points 103 to be arranged closer to the wellhead 102 on the frame 101, without requiring excessive tensioning of the tension members 104 or risking failures.

The tension members 104 can be provided on an elongate structure 120, such as a pole or rod-like structure. This is illustrated in Figs 2 and 3. A first end section 121 of the elongate structure 120 is configured for being fixed in or to one of the plurality of connection points 103 in the frame 101 and the respective tension member(s) 104 is (are) fixed to the connection point 103 via the elongate structure 120.

For example, the elongate structure 120 may have the tension member(s) 104 pre-installed and fixed to its lower part 121, and the elongate structure 120 can be arranged to be locked down into one of the connection points 103. The connection points 103 may for this purpose, for example, have a receptacle which the elongate structure 120 is placed into and then locked in place.

This is illustrated in the sequence shown between Figs 2 and 3. In Fig. 2, the wellhead assembly is arranged at a sea floor 127. On one of the wellheads 102 there is arranged a valve tree 170, such as a (so-called) Xmas tree. On another wellhead 102 (on the right hand side in Figs 2 and 3), it may be desirable to carry out an operation which requires a blow out preventer 105 to be landed on the wellhead 102. For this operation, the elongate structures 120 may be positioned in the connection points 103, either before or after the blow out preventer 105 is landed on the wellhead 102.

As can be seen, a holder 123 can be arranged to hold the elongate structures 120 when the elongate structure 120 is not fixed in or to the connection point 103. The holder 123 can be fixed on or to the frame 101. Optionally, the elongate structures 120 can be provided from a vessel (not shown), or from another storage position.

As illustrated in Fig. 2, an ROV 171 can be used to assist when installing the elongate structures 120 in the connection points 103. The elongate structure 120 to be installed can be supported by a wire 172 or equivalent from a vessel, or, if the ROV 171 has sufficient capacity and/or the buoyancy of the elongate structure 120 is suitable, it can be moved by ROV action alone.

In this embodiment, the elongate structures 120 are moved from the holder 123 to the connection points 103 with ROV assistance, as indicated in Figs 2 and 3, prior to landing the blow out preventer 105. As shown in Fig. 3, the blow out preventer 105 is then landed, suspended from a riser 117.

The ROV 107 may then fix the tension members 104 to the blow out preventer 105. The other, lower end 104b of the tension members 104 are at this stage already fixed in relation to the frame 101 as they are fixed to the elongate structure 120, which is locked in place in the connection points 103. The other, upper end 104a can then be fixed to the blow out preventer 105 and the tension members 104 tensioned-up.

In this example the elongate structures 120 were installed prior to landing the blow out preventer 105, however the blow out preventer 105 may equally well be landed first and then the elongate structures are installed.

The elongate structures 120 can be configured to temporarily hold the first end 104a of the tension member 104, for example by a hook, clamp, or equivalent fixation arrangement. This allows the elongate structures 120 to be moved with the tension member 104 fixed to it, with the lower end 104b of the tension member 104 fixed to the lower end section 121 of the elongate structure 120, which is being fixed to the connection points 103. The upper end 104a of the tension member 104 is temporarily fixed to the upper end section 122. When the tension member 104 is to be fixed to the blow out preventer 105, the upper end 104a can be released from the elongate structure 120 and fixed to the blow out preventer 105. This is illustrated in Fig. 3, where the ROV 107 moves the upper end 104a from the elongate structure 120 and onto the connection point 106 on the blow out preventer 105.

Advantageously, this eases the installation of the tension members 104 on the blow out preventer 105. For example, one may avoid the ROV 107 having to operate in a lower region of the wellhead assembly 100, near the well frame 101 and wellhead 102, where space may be limited and carrying out operations may be challenging.

Fig. 4 illustrates schematically a blow out preventer 105 (only shown in outline) arranged on one of the wellhead 102 and connected to a riser 117 to illustrate the load paths established by the wellhead assembly 100 according to the embodiments described above. A force F acts from the riser 117 and effects a side force (or moment) on the blow out preventer 105, for example due to drift-off or cyclic motion (e.g. due to weather) of the vessel at the sea surface. The tension members 104 are arranged so as to support the blow out preventer 105 and lead at least a part of this force down to the frame 101 and thereby into the foundation suction anchors 110, bypassing the wellhead 102. The load on the wellhead 102 and its associated components (such as conductor or casing tubulars) can thereby be reduced.

As noted above, the foundation may, alternatively, be of a different type than a suction anchor foundation as described above. Figure 5 illustrates one such alternative, with a piled foundation having one or more mud mats 111 and piles 102 securing the frame 101 to the sea floor. This foundation may, for example, be advantageous for harder ground conditions.

Fig. 5 further illustrates an embodiment where the well frame 101 is part of an integrated template structure 130. The well frame 101 comprises an upper part 101a extending upwardly from the well frame 101 and which is rigidly fixed to the well frame 101. The wellhead assembly 100 may otherwise comprise any of the aspects and options described above in relation to Figs 1-3, or any combination thereof. (Or the embodiments in Figs 1-3 may equally well have an integrated template structure 130.) The upper part 101a may, for example, be arranged to provide trawl protection, for holding hatches, for supporting various equipment to be arranged on the wellhead assembly 100 (such as pipes or other fluid handling equipment), for guiding equipment during installation (e.g., the blow out preventer 105), or other functions.

The connection points 103 may be arranged on the upper part 101a, i.e. at an elevated position compared to the (lower) frame 101. This can provide enhanced load relief capabilities, or easier installation of the tension members 104 to the frame 101.

Figs 6-8 illustrate another embodiment wherein the well frame 101 supports a single wellhead 102 and the well frame 101 is arranged fixed atop a suction anchor well foundation 140. The suction anchor well foundation 140 may, for example, be of the type described in the above-mentioned EP 3 102 771 B1. As can be seen in Fig. 7, a well tubular 141 extends downwardly from the wellhead 102 inside the suction anchor well foundation 140. The well tubular 141 can be a well casing connected to the wellhead 102. The well casing may be arranged inside a washout sleeve and/or a conductor pipe, as known in the art, or it may be a high pressure pipe directly arranged within the suction anchor well foundation 140. (See, for example, EP 3 102 771 B1.) The wellhead assembly 100 may otherwise comprise any of the aspects and options described above in relation to Figs 1-3, or any combination thereof.

The well frame 101 may comprises an upper part 101a extending upwardly from the well frame 101 and rigidly fixed to the well frame 101, similarly as in Fig. 5 and as shown in Figs 6-8, or it may comprise only the lower frame 101.

Optionally, the well frame 101 may extend outside a circumference of the suction anchor well foundation 140 and the connection points 103 can be arranged at locations of the well frame 101 which lie outside a circumference of the suction anchor well foundation 140. The connection points 103 may be arranged on the upper part 101a, as illustrated, or they may be provided on the lower frame 101, similarly as in Figs 1-3. By arranging the connection points 103 at a part of the well frame 101/101a which lies outside the circumference (i.e. horizontally outside the "footprint") of the well foundation 140, improved load relief effects can be obtained. For example, the angles of the tension members 140 when connected between the frame 101/101a and the blow out preventer 105 may be more beneficial if the connection points 103 are provided horizontally spaced from the foundation 140.

Figs 9 and 10 illustrate another embodiment wherein the well frame 101 supports a single wellhead 102 and the well frame 101 is supported on a sea floor by a plurality of suction anchors 110. As can be seen, the well frame 101 in this embodiment is supported by four suction anchors disposed about the wellhead 102 and the well. The wellhead assembly 100 may otherwise comprise any of the aspects and options described above in relation to Figs 1-3, or any combination thereof.

Illustrated schematically in Fig. 11, each tension member 104 may comprise a tensioner 115 operable to adjust a length of the tension member 104. The tensioner 115 may, for example, be of the types described in the above-referenced WO 2016/118019. Once the ends 104a,104b are fixed to their respective connection points as described above, the tensioner 115 can for example be operated by a torque tool on an ROV to tension-up each of the tension members 104.

Advantageously, the tensioner 115 is arranged closer to the first end 104a which is connected to the blow out preventer 105, than to the second end 104b which is connected to the frame 101 on the tension member 104. This may provide advantages of easier access to the tensioner 115 by an ROV when installed. For example, in an embodiment as illustrated in Figs 1-3, by providing the tensioner 115 nearer the blow out preventer 105 avoids the ROV having to operate lower down nearer the frame 101, where space may be more restricted.

Alternatively, the tensioners 115 may be provided integrated with the blow out preventer 105 or the frame 101. In such a case, the tension member 104 may be fixed between the blow out preventer 105 and the frame 101, and the tension member 104 may be tensioned-up by the integrated tensioner 115.

Optionally, one may lower the blow out preventer 105 to the wellhead 102 with a plurality of tensioners 115 pre-fixed to the blow out preventer 105. This is illustrated in Figs 12 and 13. Tensioners 115 may be arranged on the blow out preventer 105, connected to the connecting points 106. When the blow out preventer 105 is landed on the wellhead 102, an end 104c (see Fig. 12) of the tensioning member 104 can be connected to the tensioner 115, and thereby be brought into connection with the blow out preventer 105.

Fig. 14 illustrates lowering the blow out preventer 105 with the plurality of tension members 104 fixed to the blow out preventer 105 when the blow out preventer 105 is run and landed on the wellhead 102. One end of each tension member 104 is pre-fixed in connection point 106 on the blow out preventer 105. After the blow out preventer 105 is landed on the wellhead 102, the blow out preventer 105 can be locked to the well frame 101 by fixing the other end of the tension member 104 to the connection point 103 in the well frame 101. This may be done, for example, similarly as described above in relation to Figs 1-3, or in a different manner. For example, the tension members 104 may have a connector, clamp, hook, wire loop, or the like at its end to facilitate connection to the frame 101.

Advantageously, the end 104b (see Fig. 14) of each tension member 104 which is fixed to the well frame 101 is temporarily fixed to a holder 108 on the blow out preventer 105 while lowering the blow out preventer 105. The end 104b may then, after landing the blow out preventer 105 on the wellhead 102, be engaged by an ROV and connected to connection points 103 on the well frame 101.

Advantageously, for easy ROV access, the holder 108 is arranged on an upper part of the blow out preventer 105. For example, the holder 108 may be arranged higher than connection point 106, to which the other end of the tension member 104 is connected. The ROV may then move the end 104b to the relevant connection point 103, for example in the lower part of the frame as illustrated in Figs 1-4, or to an upper part 101a of the well frame 101, as illustrated in Figs 5-8.

If the end 104b should be connected to a lower part of the well frame 101 and space is limited, for example as may be the case in the examples shown in Figs 1-3 and 9-10, the tension members 104 may be provided on an elongate structure 120 which is fixed on the blow out preventer 105. This is illustrated in Fig. 15. The elongate structure 120 may, for example, be of the type(s) described above in relation to Figs 1-3. The height (length) of the elongate structures 120 may be adapted according to the particular design of the well frame 101 and associated components, and the elongate structure 120 may therefore be of longer or shorter length, according to the particular requirements in each case.

Similarly as described in relation to Figs 1-3, an end section 121 of the elongate structure 120 can be configured for being fixed in or to the connection points 103 on the well frame 101. Upon installation, i.e. when the blow out preventer 105 has been landed on the wellhead 102, the tension members 104 are fixed to their respective connection points 103 via the elongate structure 120, by moving the elongate structures 120 and fixing them in respective connection points 103. (By ROV action, and/or with assistance from a vessel, as described above.) As the other end of the tension member 104 is already fixed in connection point 106 on the blow out preventer 105, this allows the tension member 104 to be tensioned-up for fixing the blow out preventer 105 to the frame 101 and provide wellhead load relief. The tension members 104 may be of the type shown in Fig. 11, with a tensioner 115 arranged thereon, for example to be engaged by an ROV when the tension member 104 is ready to be tensioned-up. Alternatively, as described above, the tensioner 115 may also be provided in or on the blow out preventer 115.

In any of the examples described above, the tension members 104 may be any elongate units configured to operate in tension, such as wires, chains, rods, or the like. For example, steel wires may be suitable for use as tension members 104. By the term tension members 104 is thus meant an elongate structure configured to be pre-tensioned and to take tension loads, but not necessarily compression loads.

In any of the examples described above, the connection points 103,106 may be any arrangement operable to attach and/or lock the tension members 104 (alternatively via an intermediate component, such as the elongate structures 120), for example a clamp, a receptacle arranged to receive and hold a pin or equivalent, a hook, or a pollard arranged to hold a wire loop.

In any of the examples described above, the connection points 106 may advantageously be provided towards the top of the blow out preventer 105. For example, the connection points may be provided on the upper half of the blow out preventer 105, on the upper 30% of the blow out preventer 105, on the upper 20% of the blow out preventer 105 or on the upper 10% of the blow out preventer 105, in relation to the total height of the blow out preventer 105 when in the upright, installed position on the wellhead 102. By arranging the connection points 106 towards the top of the blow out preventer 105, enhanced wellhead load relief characteristics can be obtained.

Embodiments as described above thus may provide an easy-to-install arrangement with very good ROV access during installation, connection and activation of the wellhead load relief system.

As will be understood, if the tension members 104 can be arranged symmetrically, an efficient load transfer between blow out preventer 105 and the well frame 101 can be obtained, which provides advantages in relation to ensuring correct pre-tensioning, and also gives time savings and less risk of errors.

The main goal with the WLR system is to improve the fatigue performance of the wellhead by decreasing the load seen by the potential fatigue hotspots in the system.

In one aspect, there is provided a subsea wellhead assembly 100 as illustrated in Figs 16, 20 and 21. The assembly 100 comprises a suction anchor wellhead foundation 140 having a top part 142 through which a well tubular 141 (see Fig. 21) can extend. The well tubular 141 may be a conductor, i.e. a low-pressure pipe which holds a high-pressure pipe inside it, as illustrated in Fig. 21, or it may be a high-pressure pipe such as well casing connected to a wellhead 102 (see Fig. 16) if no conductor pipe is used.

A frame structure 101 is fixed on the top part 142. The frame structure supports a top part 141a of the well tubular 141 (in this case, a conductor pipe) in a receptacle 101d. When the well tubular 141 is run, the top part 141a will thus be lowered into the receptacle 101d and locked in place. (In this case, the top part being the conductor housing and the receptacle 141 being a conductor receptacle, however the wellhead assembly 100 may be arranged for receiving a high-pressure pipe in the receptacle 101d.) Ultimately, the receptacle 101d will support the wellhead 102, either directly or indirectly via other components, such as the conductor housing.

A wash out sleeve 147 can be provided extending downwardly from the top part 142 and inside the suction anchor wellhead foundation 140 to assist the initial stages of drilling, and through which the well tubular 141 can be installed.

Piping 148 for handling cement and cuttings during drilling and installation may be provided, in the manners known in the art.

The frame structure 101 comprises a plurality of beams 101b,c extending radially outwardly from the centrally arranged receptacle 101d supporting the wellhead 102. The beams 101b,c may comprise a substantially upright central plate, which is arranged perpendicularly to a top plate 142a of the suction anchor wellhead foundation 140. The beams 101b,c are fixed to the top plate 142a at one or more points along the length of the beams 101b,c. The beams 101b,c may be welded to the top plate 142a along substantially the entire length of the beams 101b,c, whereby a lower part of the beams 101b,c becomes fixed to the top plate 142a.

The frame structure 101 comprises a plurality of connection means 103 arranged for fixing a wellhead load relief structure 104,120,250 (described elsewhere herein) to the frame structure 101. The connection means 103 may be receptacles for receiving, for example, a tension member 104 (which could be via an elongate structure 120 as described above), a frame 250 (as described below), or any other type of load relief structure operable to support a valve tree or a blow out preventer on the frame structure 101.

Advantageously, the frame structure 101 extends outside a perimeter of the suction anchor wellhead foundation 140 and the connection means 103 are arranged on a part of the frame structure 102 which lies outside the perimeter of the suction anchor wellhead foundation 140. As can be seen from Figs 16, 20 and 21, the foundation 140 has a substantially circular horizontal cross-section, i.e. a substantially circular “footprint” on the sea bed. By providing the connection means 103 outside this “footprint”, i.e. outside the horizontal periphery of the foundation 140, improved load relief properties and/or simplified installation of the load relief structure 104,120,250 may be obtained.

Illustrated in Fig. 17, the assembly 100 may comprise a production flow base 143 having a plurality of flow control components, the production flow base 143 being arranged on the top part 142. A valve tree 149 (for example, a so-called Christmas tree) may be provided on the wellhead 102. The valve tree 149 may have fluid connections to components on the flow base 143. The production flow base 143 may be (directly or indirectly) supported by the frame structure 101. The production flow base 143 has a flow base frame 143a onto which the plurality of flow control components are mounted, for example piping, valves, or other flow conditioning or flow control components. The flow base frame 143 may extend outside a perimeter of the suction anchor wellhead foundation 140, in order to provide sufficient space and appropriate relative positioning of components on the flow base 143.

Optionally, the production flow base 143 can be fixed to the suction anchor wellhead foundation 140 via the connection means 103.

Illustrated in Figs 18 and 19, the subsea wellhead assembly 100 may comprise at least one protective hatch 144a,b pivotably fixed to the foundation 140. In this embodiment, the assembly 100 comprises two protective hatches 144a,b pivotably fixed to the foundation 140 and arranged to open in opposite directions, as can be seen in Fig. 19. In this embodiment, the hatches 144a,b are fixed to the flow base frame 143a. Alternatively, the hatches 144a,b can be fixed to another point on, or connected to, the foundation 140. In a preferred embodiment, the hatches 144a,b are anchored in the connection means 103, either directly or via an intermediate structure. This provides for a secure arrangement of the hatches 144a,b to the foundation 140.

The protective hatches 144a,b are movable between an open and a closed position, as illustrated in Figs 18 and 19. In a closed position, shown in Fig. 18, the hatches 144a,b define an opening 146 through which at least one fluid connector 145 arranged on the flow base frame 143a is accessible. As can be seen, in the illustrated embodiment, three fluid connectors are provided. The fluid connector 145 may, for example, provide for a flowline jumper (not shown) to be connected to the flow base 143 via the fluid connector 145, and through the opening 146.

The hatches 144a,b may thus provide protection of the valve tree 149 and the flow base 143 and associated components when the assembly 100 is installed, for example trawl protection or protection against dropped objects.

Advantageously, the protective hatches 144a,b are pivotable about an axis which is parallel to an access direction of the opening 146. The protective hatches 144a,b can be hinged on or adjacent a side edge of the flow base frame 143a. This allows the protective hatches 144a,b to be moved between the open and closed positions without interfering with the flow connections to fluid connector 145.

Referring now again to Figs 6-8, the subsea wellhead assembly 100 may have a frame structure 101 which comprises a lower frame part fixed on the top part 142 and an upper frame part 101a extending upwardly from the lower frame part and rigidly fixed to the lower frame part.

Advantageously, the connection means 103 may be arranged on the upper frame part 101a. The upper frame part 101a may have a central opening to receive a blow out preventer 105 (see Fig. 8) therein, with the upper frame part 101a providing a structure which at least partly surrounds the blow out preventer 105.

Advantageously, the upper frame part 101a comprises a trawl protection structure 150.

Similarly as in Figs 16-21, the assembly 100 shown in Figs 6-8 may comprise beams 101b,c which are welded or in other ways fixed onto the top plate 142a. An extension of the beams 101b,c, which may be the beams 101b,c which are fixed ot the top plate 142a themselves or other beams connected to the beams 101b,c fixed to the top plate 142a, may extend outside the footprint of the suction anchor wellhead foundation 140, as described above.

Embodiments as shown in Figs 6-8 and 16-21 provide an improved suction anchor wellhead foundation-based assembly, which can provide advantages in the form of a more optimal load path for wellhead load relief use, easier and more efficient installation, and more efficient manufacturing.

In one aspect, illustrated in Figs 22-28, there is provided a subsea wellhead assembly 200 having a well frame 201 supporting at least one wellhead 202. A support frame 250 is releasably fixed to the well frame 201. A blow out preventer 205 is arranged on the at least one wellhead 202 and a plurality of support members 251 (see Fig 23) are arranged between the support frame 250 and the blow out preventer 205.

The support frame 250 is releasably fixed to the well frame 201 via a plurality of first connectors 252 engaging a plurality of second connectors 203 (see Figs 22 and 24) arranged in the well frame 201. The first connectors 252 may, for example, have a prong arranged to cooperate with a receiver forming part of the second connector 203, as illustrated. In this manner, a receiver of each second connector 203 is operable to receive at least a part of the respective first connector 252 and hold the first connector 252 fixed when the support frame 250 is fixed to the well frame 201.

Advantageously, the plurality of second connectors 203 are disposed about the wellhead 202 on the well frame 201. The well frame 201 may define a plane in which the second connectors 203 are disposed and the at least one wellhead 202 may intersect the plane defined by the well frame 201. This provides the second connectors 203 in the same plane, i.e. the same vertical height, as the wellhead 202.

Advantageously, there are four pairs of first and second connectors 252,203 fixing the support frame 250 to the well frame 201, however more or fewer connector pairs may be possible.

There may be four support members 251 arranged between the support frame 250 and the blow out preventer 205. The support members 251, illustrated only schematically in Figs 22-25, may comprise a hydraulically extendible support member which engages a strong point on the blow out preventer 205 and applies a compressive (push) force from the support frame 250 onto the blow out preventer 205. The support members 251 may, for example, be such support members described below in relation to Fig. 29. Alternatively, the support members 251 may engage the blow out preventer 205 and be tensioned-up to provide a tension (pull) force on the blow out preventer 205.

In any of the embodiments described herein, each of the plurality of support members 251 may comprise a damper configured for engaging the blow out preventer 205 and providing a dampening force acting on the blow out preventer 205 while the blow out preventer 251 is lowered onto the wellhead 202. For example, the support members 251 may extend upwardly from the support frame 250 so as to engage the blow out preventer 205 when this is lowered from a topside vessel but prior to engaging the wellhead 202. The blow out preventer 205 may be landed on the support members 251 for this purpose. The support members 251 may provide a dampening force acting on the blow out preventer 205 to reduce and/or control its vertical speed when engaging the wellhead 202. This may, for example, be done by employing hydraulic cylinders in or in relation to the support members 251 (for example in the support frame 250), the extension of which is throttled or controlled in another way while the blow out preventer 205 is lowered onto the wellhead 202 while engaged by the support members 251. Advantageously, this can allow a more controlled installation of the blow out preventer 205 onto the wellhead 202, and reduce the risk of damage or incorrect engagement.

Illustrated most clearly in Figs 26 and 27, each support member 251 may engage a lower corner 253 of the blow out preventer 205. This allows the support frame 250 to have a low height, while still providing adequate support to the blow out preventer 205. The support frame 250 may then be positioned predominantly or full below the main body of the blow out preventer 205.

The well frame 201 may comprises one or more guide posts 225 such that the support frame 250 can engage the guide post(s) 225 for positioning of the support frame 250 in relation to the well frame 201 upon installation. Illustrated in Fig. 23, the installation process may utilise guide wires 254 from a topside vessel during installation of the support frame 250, or, alternatively, the support frame 250 may for example be guided onto the guide posts 225 using an ROV. The support frame 250 comprises one or more corresponding receivers 226 (see Fig. 23) through which the guide posts 225 extend when the support frame 250 is fixed to the well frame 201.

Figure 27 illustrates a wellhead assembly 200 having a support frame 250 as described above. Similarly as described in relation to Fig. 3 above, the blow out preventer 205 is connected to a riser 217. A valve tree 270 is arranged on one wellhead 202 of the well frame 201 and the blow out preventer 205 is arranged on another wellhead 202. Tubulars 241, such as conductor casing or well casing, extends downwardly from each wellhead 202. The support frame 250 supports the blow out preventer 205 as described above. An ROV 207 assists in connecting the blow out preventer 205 to the wellhead 202 and to the support frame 250.

As illustrated, the well frame 201 can be supported on the sea floor 227 by a plurality of suction anchors 210. Alternatively, the well frame 201 is supported on the sea floor 227 by one or more mud mats 111, as described above in relation to Fig. 5, and one or more piles 102. Similarly, the well frame 201 may be part of an integrated template structure 130 (see Fig. 5), where the well frame 201 comprises a part 101a extending upwardly from the well frame 201 and rigidly fixed to the well frame 201. In such an embodiment, the second connectors 203 may be disposed are elevated in relation to the at least one wellhead 202, for example on the part 101a extending upwardly from the well frame 201.

Similarly as shown in Figs 16-21, the well frame 201 may support a single wellhead 202 and the well frame 201 may be arranged fixed atop a suction anchor well foundation 140 through which a well casing 141 extends downwardly from the wellhead 202. The well frame 201 and assembly 200 may, in other words, be applied to the embodiments shown in Figs 16-21 in place of well frame 101.

The well frame 202 may, in such an embodiment, extend outside a circumference of the suction anchor well foundation 140, and the second connectors 203 can be arranged at locations of the well frame 201 which lie outside a circumference of the suction anchor well foundation 140.

In this embodiment, the well frame 201 may also comprise a part 101a extending upwardly from the well frame 201, as in Fig. 8, and rigidly fixed to the well frame 201. In other words, the well frame 201 may be arranged as well frame 101 shown in Fig. 8. The second connectors 203 may then be arranged on the upwardly-extending part 101a. With reference to Fig. 8, the support frame 250 may in other words be arranged on the connection points 103, where the connection points 103 make up the second connectors 203. The support frame 250 may thus support the blow out preventer 205 with support members 251 which extend from the support frame 250 and inwardly towards the blow out preventer 205, similarly as tension members 104 as illustrated in Fig. 8.

Optionally, the well frame 201 may support a single wellhead 202 with the well frame 201 being supported on the sea floor 227 by a plurality of suction anchors 110, similarly as illustrated in Figs 9-10.

The assembly 200 may thus provide a WLR system that provides a stiff connection between the dedicated WLR points on the template / well frame and the blow out preventer, for example to a lower part of the blow out preventer.

By providing the support frame 250 as a separate WLR frame, the support members 251 can be arranged in correct position before the blow out preventer 205 is landed. The support members 251 may, for example, comprise steel rods. In the embodiments shown, the support frame 250 can be secured in the four dedicated WLR connectors 203 in the well frame 201, and locked in place prior to landing the blow out preventer. This also ensures that the other end of the support members 251 is located correctly in order to connect to the blow out preventer.

Advantageously, the connectors 203 may be disposed about the wellhead 201 with a distance which is outside a horizontal footprint of the blow out preventer 205. This permits the support members 251 to be arranged with an advantageous angle towards the blow out preventer 205 to provide better load relief performance.

The ROV panel for pre-tensioning and locking between the blow out preventer and the connection at the top end of the support members 251 may be located on the blow out preventer and thus be made easily accessable by ROV.

The installation and operations to activate the WLR assembly 200 may thus include:

1) Lowering the support frame 250 to the well frame 201, for example using guidewires and well frame guide posts 225;
2) Land the support frame 250 onto the well frame 201 and the second connectors 203, and lock the support frame 250 in position;
3) Land the blow out preventer 205 and engage the blow out preventer 205 with the top end of the pre-installed support members 251. The support frame 250 thus ensures that the support members 251 are within catch range of the BOP mounted activation system;
4) Connect an electrical or hydraulic connector to the activation system;
5) Power up a topside controller and perform a controlled, balanced pre-tensioning of the support members 251.

Fig. 28 illustrates schematically a blow out preventer 205 (only shown in outline) arranged on one of the wellhead 202 and connected to a riser 217 to illustrate the load paths established by the wellhead assembly 200 according to the embodiments described above. A force F acts from the riser 217 and effects a side force (or moment) on the blow out preventer 205, for example due to drift-off or cyclic motion (e.g. due to weather) of the vessel at the sea surface. The support frame 250 is arranged so as to support the blow out preventer 205 and lead at least a part of this force down to the frame 201 and thereby into the foundation suction anchors 210, bypassing the wellhead 202. The load on the wellhead 202 and its associated components (such as conductor or casing tubulars) can thereby be reduced.

Figures 29-36 illustrate other embodiments of a subsea wellhead assembly 200 having a well frame 201 supporting at least one wellhead 202 as above, and having a support frame 250 releasably fixed to the well frame 201 (Figs 31-35). As above, a blow out preventer 205 can be arranged on the wellhead 202 and fixed thereto. In these embodiments, the support frame 250 forms a receptacle 260 (Fig. 29) in which the blow out preventer 205 is at least partly arranged when fixed on the wellhead 202, as can be seen in Figs 31 and 32. The support frame 250 in these embodiments is thus formed as a “cage” for the blow out preventer 205.

A plurality of support members 251 are arranged between the support frame 250 and the blow out preventer 205. The support members 251 are illustrated in relation to Fig. 29; similar support members 251 will be used in the arrangements shown in Figs 30-35 but are for simplicity not shown here. The support members 251 may be arranged on horizontal beams at or near the upper part of the support frame 250, as shown in Fig. 29, or, alternatively or additionally, on vertical beams of the support frame 250, such as on the vertical, corner beams extending downwardly towards the connectors 252.

When the blow out preventer 205 is arranged in the receptacle 260, the support members 251 are activated to provide sideways support for the blow out preventer 205. A side force acting, for example, from a riser 217 (see Fig. 28) can thereby be reduced such that as to reduce the exposure of the wellhead 202 to bending loads. The support members 251 may, for example, be extendible and retractable arms such as those described in the abovementioned WO 2019/103625 A1. The support members 251 may thus be extended to engage strong points on the blow out preventer 205, whereby a stiff or substantially rigid connection is formed to transfer forces from the blow out preventer 205 to the support frame 250. As the support frame 250 is fixed to the well frame 201, such forces will be taken up in the foundation, e.g. in suction anchors 210.

As can be seen from Fig 29, the plurality of support members 251 can be arranged laterally between the support frame 250 and the blow out preventer 205.

The support frame 250 may comprise a first, lower part 250a and a second, upper part 250b which are releasably connectable via intermediate connectors 261. This is illustrated in Fig. 30. The support frame 250 is thus made up of two parts, which can be selectively interconnected in a rigid manner. The connectors 261, when engaged, are able to transfer loads between the upper and lower parts. Fig. 35 illustrates the support frame 250 in an installed position (the blow out preventer 205 is not shown).

As illustrated in Figs 31-35, the subsea wellhead assembly 200 may comprise one or more hatches 263. Each hatch 263 has a closed position where the hatch 263 is closed above the wellhead 202 and an open position where the wellhead 202 is accessible from above.

Advantageously, the at least one hatch 263 may have a closed position where the hatch 263 is closed above the wellhead 202 with the support frame 250 arranged on the well frame 201. This is illustrated in Figs 33-34. This may allow the support frame 250 to be installed together with the well frame 201 and remain in place until for example a drilling operation starts, while the hatch(es) 263 can be closed in a time between the installation of the well frame 201 and the start of the drilling operation, for example to provide trawl protection during this time. Alternatively this may allow a drilling or well intervention operation to be paused, with the support frame 250 remaining in place until the operation is continued, but with the hatch(es) 263 closable in the meantime. This can be obtained by arranging the support frame 250 sufficiently low in relation to the hatch 263 design such that the hatch 263 can close above the support frame 250.

As also illustrated in Figs 33 and 34, the wellhead assembly 200 may have a plurality of wellheads 202 and a plurality of support frames 250 fixed on the well frame 201. This may allow a multi-slot well frame 201 to be installed with a support frame 250 arranged at each wellhead slot. When, for example, drilling operations commence on one wellhead slot, the support frame 250 is already in place and need not be separately installed. When the well is completed, the support frame 250, which is releasably connected to the well frame 201, can be removed, and, for example, a valve tree (such as valve tree 270 in Fig. 27) can be installed.

The support frame 250 arranged as described in the preceding two paragraphs may be a support frame such as those described in relation to Figs 29-35, or it may be a support frame such as that described above in relation to Figs 22-27.

Advantageously, if using a two-part support frame 250 with the lower part 250a arranged on the well frame 201, only the lower part 250a can be arranged to allow the hatch 263 to close above it. This may allow the use of a lower hatch 263, while still providing adequate load relief via the support frame 250, which includes the upper part 250b when in use. The upper part 250b may then be run and locked on the lower part 250a prior to use, which provides for an easier connection than connecting the support frame 250 to the well frame 201.

Advantageously, when carrying a well operation via the subsea wellhead 202, such as drilling or well intervention, one may run the blow out preventer 205 from a vessel with the upper part 250b of the support frame 250 fixed to it. The blow out preventer 205 can then be landed on the wellhead 202, and the upper part 250b connected to the lower part 205a.

This allows the lower part 250a to have been pre-installed on the well frame 201, for example before installation of the well frame 201, or by a separate (typically lighter) vessel prior to running the blow out preventer 205 and starting the well operation.

In an arrangement as shown in Figs 33 and 34, if running the upper part 250b pre-installed on the blow out preventer 205, on may carry out a well operation on one wellhead, and then move the blow out preventer 205 with the upper part 250b to another wellhead slot and connect the upper part 250b to another lower part, pre-installed on that wellhead slot. In that way, there is no need to retrieve and re-install the support frame 250 separately when switching between wells.

Illustrated in Fig. 30, the lower part 250a may optionally comprise a side opening 262. This may reduce space constraints at or near the well frame 201, without substantially reducing the structural capacity of the support frame 250.

Fig. 36 shows a top view of a part of the well frame 201, illustrating the wellhead 202 and the connectors 203. Advantageously, if the well frame 201 comprises more than one wellhead 202, the connectors 203 may be shared between wellheads arranged next to each other. In other words, some of the connectors 203 may be operable to support a support frame 250 when the support frame 250 is arranged at different wellheads. For example, in relation to Fig. 36, if the well frame 201 comprises another wellhead 202 at the right hand side (as seen) from the shown wellhead 202, then the two right-hand connectors 203 may be used with a support frame 250 when arranged on the visible wellhead 202, and they may be used with a support frame 250 on the other wellhead at a later time, or optionally, the support frame 250 may extend to provide support at both wellheads. This eases design and manufacturing of the well frame 201, which requires less connectors 203 in such a case.

The support frame 250 described in relation to Figs 29-35 may otherwise comprise any, or any combination, of features described above in relation to Figs 22-27.

Thus, according to these embodiments, a wellhead load relief (WLR) system can be designed to "relieve" the wellhead, by transferring a part of the loads (dynamic and/or static) from the blow out preventer (BOP) into the template structure. The WLR system may reduce the loads as seen by the wellhead, ensuring improved wellhead design life. The blow out preventer 205 is supported and sideways motion is reduced or prevented.

If using a two-part support frame 250, or “cage”, as described above, the lower and upper cages can be lifted by crane as separate lifts from a rig or vessel. The upper cage can be moved together with the BOP between slots on the same template. The manifold can be installed without retrieval of the lower BOP cage(s). The lower BOP cage can be pre-installed on some or all wellhead slots while still allowing the hatches to be closed to ensure overtrawlability and protection of the wellhead assembly.

Advantageously, if using a two-part support frame 250 / cage, the upper part can be adapted for the specific BOP in question, while having the same interface (connectors 261) to the lower part. This allows the use of different BOPs, for example in that only the upper part needs to be adapted if the BOP design varies. Moreover, if pre-installing the support frame(s) 250 on the well frame 201 / template before knowing which rig / which BOP will be used, the pre-installed, lower part 250a is still usable since only the upper part 250b needs to be adapted to “fit” the BOP in question.

The lower part 250a may, alternatively, be installed after the well frame 201 / template is installed. This may, for example, be carried out by a lighter vessel than that installing the BOP and carrying out the well operation.

Illustrated in Figs 37-39, in one embodiment there is provided a subsea wellhead assembly 300 comprising a well frame 301 arranged on a sea floor 398 and supporting a wellhead 302. A blow out preventer 305 is arranged on the wellhead 302, and a plurality of anchors 399 are disposed on and secured to the sea floor about the well frame 301. The well frame 301 may be a template or a suction anchor foundation, i.e. the well frame 301 may be fixed atop a suction anchor foundation or be made up by a suction anchor foundation and be integrally formed with this. (See, for example, the examples described above.)

A plurality of tension members 304 are arranged between the plurality of anchors 399 and the blow out preventer 305. The anchors 399 may comprise a connector 391 for connecting to the tension member or members 304. The connector 391 may be arranged on a top surface of the anchors 399. The tension members 304 may, for example, be of a type according to any one of the abovementioned embodiments of tension members 104. The anchors 399 may also comprise lifting ears 392 or equivalent, for example in corners of the anchor 399 as illustrated in Fig. 38, in order to lift or lower the anchor 399. By the lifting ears 392, the anchors 399 can be lowered from a vessel to the sea floor 398 and positioned in relation to the well frame 301, prior to hooking up the tension members 304 and installing piles 397 (see below).

The subsea wellhead assembly may comprise exactly one tension member 304 extending from each anchor 399 to the blow out preventer 305. For example, the assembly 300 may comprise four anchors 399 and four tension members 304 extending to the blow out preventer from different directions. Optionally, more than one tension member 304 may extend from each anchor 399 to the blow out preventer 305. For example, as shown in Fig. 37, two tension members 304 can extend from each anchor 399.

Advantageously, each tension member 304 is arranged with a tensile preload to apply a tethering force on the blow out preventer 305.

Illustrated in Figs 38 and 39, the anchors 399 may comprise a body 396 having a plurality of holes 395, where each hole 395 configured for receiving an elongate anchoring pile 397. The anchoring piles 397 may, for example, be metal piles adapted to be driven through the holes 395 such as to secure the anchor 399 to the sea floor 398.

Advantageously, the body 396 comprises a substantially flat plate 394 through which the holes 395 extend.

Advantageously, the body 396 comprises more than 5, more than 10, more than 15 or more than 20 holes 395.

As illustrated in Fig. 37, the blow out preventer 305 may have four connection points and two tension members 304 may extend from each of the anchor 399 and being fixed to different connection points on the blow out preventer 305. For example, the two tension members 304 may be fixed to diagonally opposite connection points on the blow out preventer 305. The two tension members 304 may advantageously be fixed to connection points on the blow out preventer 305 which are spaced between a closest and a farthermost connection point on the blow out preventer 305, as illustrated in Fig. 37, where each tension member 304 extends not to the closest corner of the blow out preventer 305 but to one of the diagonally opposite corners farther away from the closest corner.

By implementing one or more of these arrangement options, an improved load distribution in the tension members 304 can be obtained. This can give enhanced load relief properties for the wellhead assembly 300 in that pre-tensioning of the tension members 304 is made easier. It may, for example, also be advantageous to let all tension members 304 have the same length and structural properties (such as material stiffness). This can avoid problems associated with obtaining accurate pre-tensioning in systems having different length, angle, or other characteristics between the tension members 304, thereby increasing accuracy, installation time and risk of incorrect pre-tensioning settings.

According to embodiments illustrated in Figs 37-39 and described above, enhanced load relief properties, enhanced operational flexibility, or other advantages could be realised. For example, in use, the length and number of piles 397 may be chosen according to the soil conditions and hardness in a given case. This provides operational flexibility in that, for example, an additional anchoring effect can be realized, for example, by increasing the number of piles 397 in case poor soil conditions are experienced or increased tethering forces are required. The anchors 399 may, for this purpose, be arranged with a larger number of holes 395 than what would be required in the least demanding applications, in order to achieve such flexibility. Similarly, the size of the anchor 399, for example the size of a plate 394 making up the anchor 399 may be chosen according to a particular application and requirements. Advantages of embodiments described herein may also, for example, include flexibility if the equipment is required to be used at different locations with different conditions and operating requirements.

The following clauses further outline inventive aspects and embodiments according to the present disclosure.

1. A subsea wellhead assembly (100) having a well frame (101) supporting at least one wellhead (102),
   a plurality of connection points (103) arranged in the well frame (101) and disposed about the at least one wellhead (102),
   a blow out preventer (105) arranged on the at least one wellhead (102),
   a plurality of tension members (104) arranged between the plurality of connection points (103) and the blow out preventer (105).

2. A subsea wellhead assembly (100) according to the preceding clause, wherein the connection points (103) are disposed in a plane which the at least one wellhead (102) intersects.

3. A subsea wellhead assembly (100) according to any preceding clause, wherein the blow out preventer (105) has four connection points (106), and wherein from each of the plurality of connection points (103) in the well frame (101) there extends two tension members (104) which are fixed to different connection points (106) on the blow out preventer (105).

4. A subsea wellhead assembly (100) according to the preceding clause, wherein the two tension members (104) are fixed to diagonally opposite connection points (106) on the blow out preventer (105).

5. A subsea wellhead assembly (100) according to any preceding clause, wherein the two tension members (104) are fixed to connection points (106) on the blow out preventer (105) which are spaced between a closest and a farthermost connection point (106) on the blow out preventer (105).

6. A subsea wellhead assembly (100) according to any preceding clause, wherein the plurality of connection points (103) are disposed symmetrically about the at least one wellhead (102).

7. A subsea wellhead assembly (100) according to any preceding clause, wherein at least one of the plurality of tension members (104) is provided on an elongate structure (120), a first end section (121) of the elongate structure

(120) configured for being fixed in or to one of the plurality of connection points (103),
and wherein the at least one tension member (104) is fixed to the respective connection point (103) via the elongate structure (120).

8. A subsea wellhead assembly (100) according to the preceding clause, wherein the elongate structure (104) is configured to temporarily hold a first end (104a) of the tension member (104).

9. A subsea wellhead assembly (100) according to any of the two preceding clauses, wherein a second end (104b) of the tension member (104) is fixed to the first end section (121).

10. A subsea wellhead assembly (100) according to any of the three preceding clauses, comprising a holder (123) arranged to hold the elongate structure (120) when the elongate structure (120) is not fixed in or to the connection point (103).

11. A subsea wellhead assembly (100) according to any preceding clause, wherein the well frame (101) is supported on a sea floor (127) by a plurality of suction anchors (110).

12. A subsea wellhead assembly (100) according to any preceding clause, wherein the well frame (101) is supported on a sea floor (127) by one or more mud mats (111) and one or more piles (102).

13. A subsea wellhead assembly (100) according to any preceding clause, wherein the well frame (101) is part of an integrated template structure (130), wherein the well frame (101) comprises a part (101a) extending upwardly from the well frame (101) and rigidly fixed to the well frame (101), wherein the connection points (103) are arranged on the part (101a).

14. A subsea wellhead assembly (100) according to any preceding clause, wherein a plane in which the connection points (103) are disposed are elevated in relation to the at least one wellhead (102).

15. A subsea wellhead assembly (100) according to any preceding clause, wherein the well frame (101) supports a single wellhead (102) and the well frame (101) is arranged fixed atop a suction anchor well foundation (140) through which a well casing (141) extends downwardly from the wellhead (102).

16. A subsea wellhead assembly (100) according to any preceding clause, wherein the well frame (101) extends outside a circumference of the suction anchor well foundation (140).

17. A subsea wellhead assembly (100) according to any preceding clause, wherein the connection points (103) are arranged at locations of the well frame (101) which lie outside a circumference of the suction anchor well foundation (140).

18. A subsea wellhead assembly (100) according to any of the preceding clauses, wherein the well frame (101) comprises a part (101a) extending upwardly from the well frame (101) and rigidly fixed to the well frame (101), and wherein the connection points (103) are arranged on the part (101a).

19. A subsea wellhead assembly (100) according to any preceding clause, wherein the well frame (101) supports a single wellhead (102) and the well frame (101) is supported on a sea floor (127) by a plurality of suction anchors (110).

20. A subsea wellhead assembly (100) according to any preceding clause, wherein each tension member (104) comprises a tensioner (115) operable to adjust a length of the tension member (104).

21. A subsea wellhead assembly (100) according to the preceding clause, wherein the tensioner (115) is arranged closer to the first end (104a) than to the second end (104b) on the tension member (104),

22. A subsea wellhead assembly (100) according to any preceding clause, where the least one wellhead (102) comprises a first wellhead and a second wellhead, wherein at least two of the plurality of connection points (103) are shared between the first and second wellheads, whereby two tension members (104) can be fixed via the at least two of the plurality of connection points (103) both when arranged to support a blow out preventer (105) on the first wellhead and when arranged to support a blow out preventer (105) on the second wellhead.

23. A method for controlling bending loads on a subsea wellhead (102) when connected to a riser (117), the method comprising the steps:
lowering a blow out preventer (105) connected to the riser (117) and landing the blow out preventer (105) on the wellhead (102);
arranging a plurality of tension members (104) between the blow out preventer (105) and a well frame (101) supported on a sea floor (127); and operating a tensioner (115) to provide a pre-tensioning in each tension member (104).

24. A method according to the preceding clause, wherein the step of arranging the plurality of tension members (104) between the blow out preventer (105) and the well frame (101) comprises connecting a first end (104a,104c) of the tension member (104) to the blow out preventer (105) and a second end (104b) of the tension member (104) to the well frame (101).

25. A method according to any preceding clause, wherein the step of lowering the blow out preventer (105) comprises lowering the blow out preventer (105) with a plurality of tensioners (115) fixed to the blow out preventer (105), and wherein the step of connecting the first end (104a,104c) of the tension member (104) to the blow out preventer (105) comprises connecting the first end (104a,104c) of the tension member (104) to the blow out preventer (105) via the tensioners (115).

26. A method according to any preceding clause wherein the step of lowering the blow out preventer (105) comprises lowering the blow out preventer (105) with the plurality of tension members (104) fixed to the blow out

preventer (105), and the step of arranging the plurality of tension members (104) between the blow out preventer (105) and the well frame (101) comprises fixing each tension member (104) the well frame (101).

27. A method according to the preceding clause, wherein an end (104b) of each tension members (104) to be fixed to the well frame (101) is temporarily fixed to a holder (108) on the blow out preventer (105) while lowering the blow out preventer (105).

28. A method according to the preceding clause, wherein the holder (108) is arranged on an upper part of the blow out preventer (105).

29. A method according to any preceding clause, wherein at least one of the plurality of tension members (104) is provided on an elongate structure (120), a first end section (121) of the elongate structure (120) configured for being fixed in or to a plurality of connection points (103) on the well frame (101),
and wherein, upon installation, the at least one tension member (104) is fixed to the respective connection point (103) via the elongate structure (120).

30. A method according to any preceding clause, wherein a plurality of connection points (103) are disposed on the well frame (101), the plurality of connection points (103) defining a plane which the wellhead (102) intersects.

31. A subsea wellhead assembly (100) comprising a suction anchor wellhead foundation (140) having a top part (142) through which a well tubular (141) extends,
a frame structure (101) fixed on the top part (142), the frame structure supporting a wellhead (102).

32. A subsea wellhead assembly (100) according to any preceding clause, wherein the frame structure (101) comprises a plurality of connection means (103) arranged for fixing a wellhead load relief structure (104,120,250) to the frame structure (101).

33. A subsea wellhead assembly (100) according to any preceding clause, wherein the frame structure (102) extends outside a perimeter of the suction anchor wellhead foundation (140) and the connection means (103) are arranged on a part of the frame structure (102) which lies outside the perimeter of the suction anchor wellhead foundation (140).

34. A subsea wellhead assembly (100) according to any preceding clause, comprising a production flow base (143) having a plurality of flow control components, the production flow base (143) being arranged on the top part (142).

35. A subsea wellhead assembly (100) according to any preceding clause, wherein the production flow base (143) has a flow base frame (143a) onto which the plurality of flow control components are mounted, and wherein the flow base frame (143) extends outside a perimeter of the suction anchor wellhead foundation (140).

36. A subsea wellhead assembly (100) according to any preceding clause, wherein the production flow base (143) is fixed to the suction anchor wellhead foundation (140) via the connection means (103).

37. A subsea wellhead assembly (100) according to any preceding clause, comprising at least one protective hatch (144a,b) pivotably fixed to the suction anchor wellhead foundation (140).

38. A subsea wellhead assembly (100) according to the preceding clause, comprising two protective hatches (144a,b) pivotably fixed to the suction anchor wellhead foundation (140) and arranged to open in opposite directions.

39. A subsea wellhead assembly (100) according to any preceding clause, wherein the at least one protective hatch (144a,b) is connected to the suction anchor wellhead foundation (140) via the flow base frame (143a).

40. A subsea wellhead assembly (100) according to any preceding clause, wherein the at least one protective hatch (144a,b) in a closed position thereof comprises an opening (146) through which at least one fluid connector (145) arranged on the flow base frame (143a) is accessible.

41. A subsea wellhead assembly (100) according to the preceding clause, wherein the at least one protective hatch (144a,b) is pivotable about an axis which is parallel to an access direction of the opening (146).

42. A subsea wellhead assembly (100) according to any preceding clause, wherein the frame structure (101) comprises a plurality of beams (101b,c) extending radially outwardly from a centrally arranged receptacle (101d) for a wellhead (102).

43. A subsea wellhead assembly (100) according to the preceding clause, wherein the connection means (103) are arranged on respective beams (101b,c).

44. A subsea wellhead assembly (100) according to any preceding clause, wherein the beams (101b,c) extend radially outwardly beyond the perimeter of the suction anchor wellhead foundation (140) and the connection means (103) are arranged on respective beams (101b,c) outside the perimeter of the suction anchor wellhead foundation (140).

45. A subsea wellhead assembly (100) according to any preceding clause, wherein the frame structure (101) comprises a lower frame part fixed on the top part (142) and an upper frame part (101a) extending upwardly from the lower frame part and rigidly fixed to the lower frame part.

46. A subsea wellhead assembly (100) according to the preceding clause, wherein the connection means (103) are arranged on the upper frame part (101a).

47. A subsea wellhead assembly (100) according to any preceding clause, wherein the upper frame part (101a) comprises a trawl protection structure (150).

48. A subsea wellhead assembly (100) according to any preceding clause, wherein the frame structure (101) is fixed onto a top plate (142a) of the suction anchor wellhead foundation (140).

49. A subsea wellhead assembly (100) according to the preceding clause, wherein the frame structure (101) comprises beams (101b,c) welded onto the top plate (142a).

50. A subsea wellhead assembly (200) having a well frame (201) supporting at least one wellhead (202),
a support frame (250) releasably fixed to the well frame (201),
a blow out preventer (205) arranged on the at least one wellhead (202),
a plurality of support members (251) arranged between the support frame (250) and the blow out preventer (205).

51. A subsea wellhead assembly (200) according to any preceding clause, wherein each of the plurality of support members (251) comprises a damper configured for engaging the blow out preventer (205) and providing a dampening force acting on the blow out preventer (205) while the blow out preventer (251) is lowered onto the wellhead (202).

52. A subsea wellhead assembly (200) according to any preceding clause, wherein the support frame (250) is releasably fixed to the well frame (201) via a plurality of first connectors (252) engaging a plurality of second connectors (203) arranged in the well frame (201).

53. A subsea wellhead assembly (200) according to any preceding clause, wherein each second connector (203) comprises a receiver operable to receive at least a part of the respective first connector (252) and hold the first connector (252) fixed when the support frame (250) is fixed to the well frame (201).

54. A subsea wellhead assembly (200) according to any preceding clause, wherein the plurality of second connectors (203) are disposed about the at least one wellhead (202) on the well frame (201).

55. A subsea wellhead assembly (200) according to any preceding clause,
wherein the well frame (201) defines a plane in which the second connectors (203) are disposed,
and the at least one wellhead (202) intersects the plane defined by the well frame (201).

56. A subsea wellhead assembly (200) according to any preceding clause, having four pairs of first and second connectors (252,203) fixing the support frame (250) to the well frame (201).

57. A subsea wellhead assembly (200) according to any preceding clause, having four support members (251).

58. A subsea wellhead assembly (200) according to any preceding clause, wherein the well frame (201) comprises one or more guide posts (225), and wherein the support frame (250) engages the one or more guide posts (225) for positioning of the support frame (250) in relation to the well frame (201).

59. A subsea wellhead assembly (200) according to any preceding clause, wherein the support frame (250) comprises one or more receivers (226) through which the guide posts (225) extend when the support frame (250) is fixed to the well frame (201).

60. A subsea wellhead assembly (200) according to any preceding clause, wherein each support member (251) engages a lower corner (253) of the blow out preventer (205).

61. A subsea wellhead assembly (200) according to any preceding clause, comprising at least one hatch (263), wherein the at least one hatch (263) has a closed position where the hatch (263) is closed above the wellhead (202) with the support frame (250) arranged on the well frame (201).

62. A subsea wellhead assembly (200) according to any preceding clause, comprising a plurality of wellheads (202) and a plurality of support frames (250) fixed on the well frame (201).

63. A subsea wellhead assembly (200) according to any preceding clause, wherein the well frame (201) is supported on a sea floor (227) by a plurality of suction anchors (210).

64. A subsea wellhead assembly (100) according to any preceding clause, wherein the well frame (101) is supported on a sea floor (227) by one or more mud mats (111) and one or more piles (102).

65. A subsea wellhead assembly (200) according to any preceding clause, wherein the well frame (201) is part of an integrated template structure (230), wherein the well frame (201) comprises a part (201a) extending upwardly from the well frame (201) and rigidly fixed to the well frame (201).

66. A subsea wellhead assembly (200) according to the preceding clause, wherein the second connectors (203) are arranged on positions on the well frame (201) which are not on the part (201a).

67. A subsea wellhead assembly (200) according to any preceding clause, wherein the well frame (201) supports a single wellhead (202) and the well frame (201) is arranged fixed atop a suction anchor well foundation (140) through which a well casing (141) extends downwardly from the wellhead (202).

68. A subsea wellhead assembly (200) according to any preceding clause, wherein the well frame (202) extends outside a circumference of the suction anchor well foundation (140).

69. A subsea wellhead assembly (200) according to any preceding clause, wherein the second connectors (203) are arranged at locations of the well frame (201) which lie outside a circumference of the suction anchor well foundation (140).

70. A subsea wellhead assembly (200) according to any preceding clause, wherein the well frame (201) comprises a part (101a) extending upwardly from the well frame (101) and rigidly fixed to the well frame (101), and wherein the second connectors (103) are arranged on the part (101a).

71. A subsea wellhead assembly (200) according to any preceding clause, wherein the well frame (201) supports a single wellhead (202) and the well frame (201) is supported on a sea floor (227) by a plurality of suction anchors (110).

72. A subsea wellhead assembly (200) according to any preceding clause, where the least one wellhead (202) comprises a first wellhead and a second wellhead, wherein at least two of the plurality of second connectors (203) are shared between the first and second wellheads, whereby a support frame (250) can be fixed via the at least two of the plurality of second connectors (203) both when arranged with the first wellhead and when arranged with the second wellheads.

73. A subsea wellhead assembly (200) having a well frame (201) supporting at least one wellhead (202);
a support frame (250) releasably fixed to the well frame (201);
a blow out preventer (205) arranged on the at least one wellhead (202);
a plurality of support members (251) arranged between the support frame (250) and the blow out preventer (205);
wherein the support frame (250) forms a receptacle (260) in which the blow out preventer (205) is at least partly arranged.

74. A subsea wellhead assembly (200) according to the preceding clause, wherein the plurality of support members (251) are arranged laterally between the support frame (250) and the blow out preventer (205).

75. A subsea wellhead assembly (200) according to any preceding clause, wherein the support frame (250) comprises a first, lower part (250a) and a

second, upper part (250b), the two parts releasably connectable via intermediate connectors (261).

76. A subsea wellhead assembly (200) according to the preceding clause, wherein the lower part (250a) comprises a side opening (262).

77. A subsea wellhead assembly (200) according to any preceding clause, comprising at least one hatch (263), wherein the at least one hatch (263) has a closed position where the hatch (263) is closed above the wellhead (202) with the lower part (250a) arranged on the well frame (201).

78. A subsea wellhead assembly (200) according to any preceding clause, comprising at least one hatch (263), wherein the at least one hatch (263) has a closed position where the hatch (263) is closed above the wellhead (202) with the support frame (250) arranged on the well frame (201).

79. A subsea wellhead assembly (200) according to any preceding clause, comprising a plurality of wellheads (202) and a plurality of support frames (250) fixed on the well frame (201).

80. A subsea wellhead assembly (200) according to any preceding clause, wherein the support frame (250) is releasably fixed to the well frame (201) via a plurality of first connectors (252) engaging a plurality of second connectors (203) arranged in the well frame (201).

81. A subsea wellhead assembly (200) according to any preceding clause, wherein each second connector (203) comprises a receiver operable to receive at least a part of the respective first connector (252) and hold the first connector (252) fixed when the support frame (250) is fixed to the well frame (201).

82. A subsea wellhead assembly (200) according to any preceding clause, wherein the plurality of second connectors (203) are disposed about the at least one wellhead (202) on the well frame (201).

83. A subsea wellhead assembly (200) according to any of the preceding clauses,

    wherein the well frame (201) defines a plane in which the second connectors (203) are disposed,

    and the at least one wellhead (202) intersects the plane defined by the well frame (201).

84. A subsea wellhead assembly (200) according to any of the preceding clauses, having four pairs of first and second connectors (252,203) fixing the support frame (250) to the well frame (201).

85. A subsea wellhead assembly (200) according to any of the preceding clauses, where the least one wellhead (202) comprises a first wellhead and a second wellhead, wherein at least two of the plurality of second connectors (203) are shared between the first and second wellheads, whereby a support frame (250) can be fixed via the at least two of the plurality of second connectors (203) both when arranged with the first wellhead and when arranged with the second wellheads.

86. A subsea wellhead assembly (200) according to any of the preceding clauses, wherein the well frame (201) comprises one or more guide posts (225), and wherein the support frame (250) engages the one or more guide posts (225) for positioning of the support frame (250) in relation to the well frame (201).

87. A subsea wellhead assembly (200) according to any preceding clause, wherein the support frame (250) comprises one or more receivers (226) through which the guide posts (225) extend when the support frame (250) is fixed to the well frame (201).

88. A subsea wellhead assembly (200) according to any of the preceding clauses, wherein the well frame (201) is supported on a sea floor (227) by a plurality of suction anchors (210).

89. A subsea wellhead assembly (100) according to any preceding clause, wherein the well frame (101) is supported on a sea floor (227) by one or more mud mats (111) and one or more piles (102).

90. A subsea wellhead assembly (200) according to any of the preceding clauses, wherein the well frame (201) is part of an integrated template structure (230), wherein the well frame (201) comprises a part (201a) extending upwardly from the well frame (201) and rigidly fixed to the well frame (201).

91. A subsea wellhead assembly (200) according to any preceding clause, wherein the second connectors (203) are arranged on positions on the well frame (201) which are not on the part (201a).

92. A subsea wellhead assembly (200) according to any of the preceding clauses, wherein the well frame (201) supports a single wellhead (202) and the well frame (201) is arranged fixed atop a suction anchor well foundation (140) through which a well casing (141) extends downwardly from the wellhead (202).

93. A subsea wellhead assembly (200) according to any preceding clause, wherein the well frame (202) extends outside a circumference of the suction anchor well foundation (140).

94. A subsea wellhead assembly (200) according to any preceding clause, wherein the second connectors (203) are arranged at locations of the well frame (201) which lie outside a circumference of the suction anchor well foundation (140).

95. A subsea wellhead assembly (200) according to any of the preceding clauses, wherein the well frame (201) comprises a part (101a) extending upwardly from the well frame (101) and rigidly fixed to the well frame (101), and wherein the second connectors (103) are arranged on the part (101a).

96. A subsea wellhead assembly (200) according to any of the preceding clauses, wherein the well frame (201) supports a single wellhead (202) and the well frame (201) is supported on a sea floor (227) by a plurality of suction anchors (110).

97. A method of carrying a well operation via a subsea wellhead (202), the method comprising:
running a blow out preventer (205) from a vessel, the blow out preventer (205) having an upper part (250b) of a support frame (250) fixed thereto;
landing the blow out preventer (205) on the wellhead (202);
connecting the upper part (250b) to a lower part (250a) of the support frame (250), the lower part (250a) having been pre-arranged fixed to a well frame (201) supporting the wellhead (202).

CLAIMS

1. A subsea wellhead assembly (300) comprising
a well frame (301) arranged on a sea floor (398) and supporting a wellhead (302),
a blow out preventer (305) arranged on the wellhead (302),
a plurality of anchors (399) disposed on and secured to the sea floor about the well frame (301), wherein
a plurality of tension members (304) arranged between the plurality of anchors (399) and the blow out preventer (305).

2. A subsea wellhead assembly (300) according to any preceding claim, wherein (i) exactly one or (ii) more than one tension member (304) extends from each of the plurality of anchors (399) to the blow out preventer (305).

3. A subsea wellhead assembly (300) according to any preceding claim, wherein the at least one tension member (304) is arranged with a tensile preload to apply a tethering force on the blow out preventer (305).

4. A subsea wellhead assembly (300) according to any preceding claim, wherein the anchors (399) comprises a body (396) having a plurality of holes (395), each hole (395) configured for receiving an elongate anchoring pile (397).

5. A subsea wellhead assembly (300) according to any preceding claim, wherein the body (396) comprises a substantially flat plate (394) through which the holes (395) extend.

6. A subsea wellhead assembly (300) according to any preceding claim, wherein the body (396) comprises more than 5, more than 10, more than 15 or more than 20 holes (395).

7. A subsea wellhead assembly (300) according to any preceding claim, wherein the blow out preventer (305) has four connection points,

and wherein from each of the anchors (399) there extends two tension members (304) which are fixed to different connection points on the blow out preventer (305).

8. A subsea wellhead assembly (300) according to the preceding claim, wherein the two tension members (304) are fixed to diagonally opposite connection points on the blow out preventer (305).

9. A subsea wellhead assembly (300) according to any of the two preceding claims, wherein the two tension members (304) are fixed to connection points on the blow out preventer (305) which are spaced between a closest and a farthermost connection point on the blow out preventer (305).

10. A subsea wellhead assembly (300) according to any preceding claim, wherein each anchor (399) comprises a connector (391) for holding one or more tension member (304).

11. A subsea wellhead assembly (300) according to any preceding claim, wherein the connector (391) is arranged on a top surface of the anchor (399).

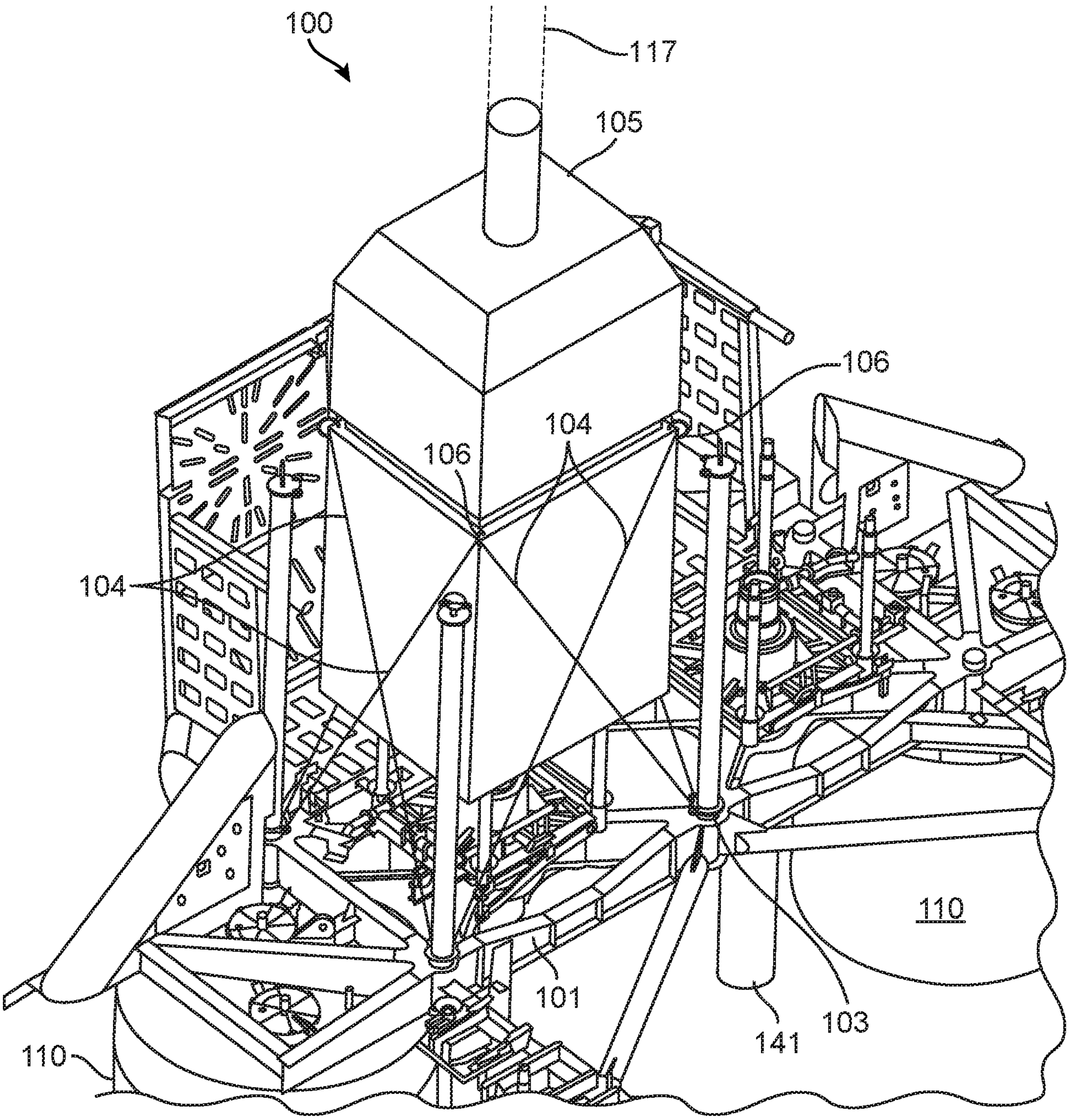



FIG. 1

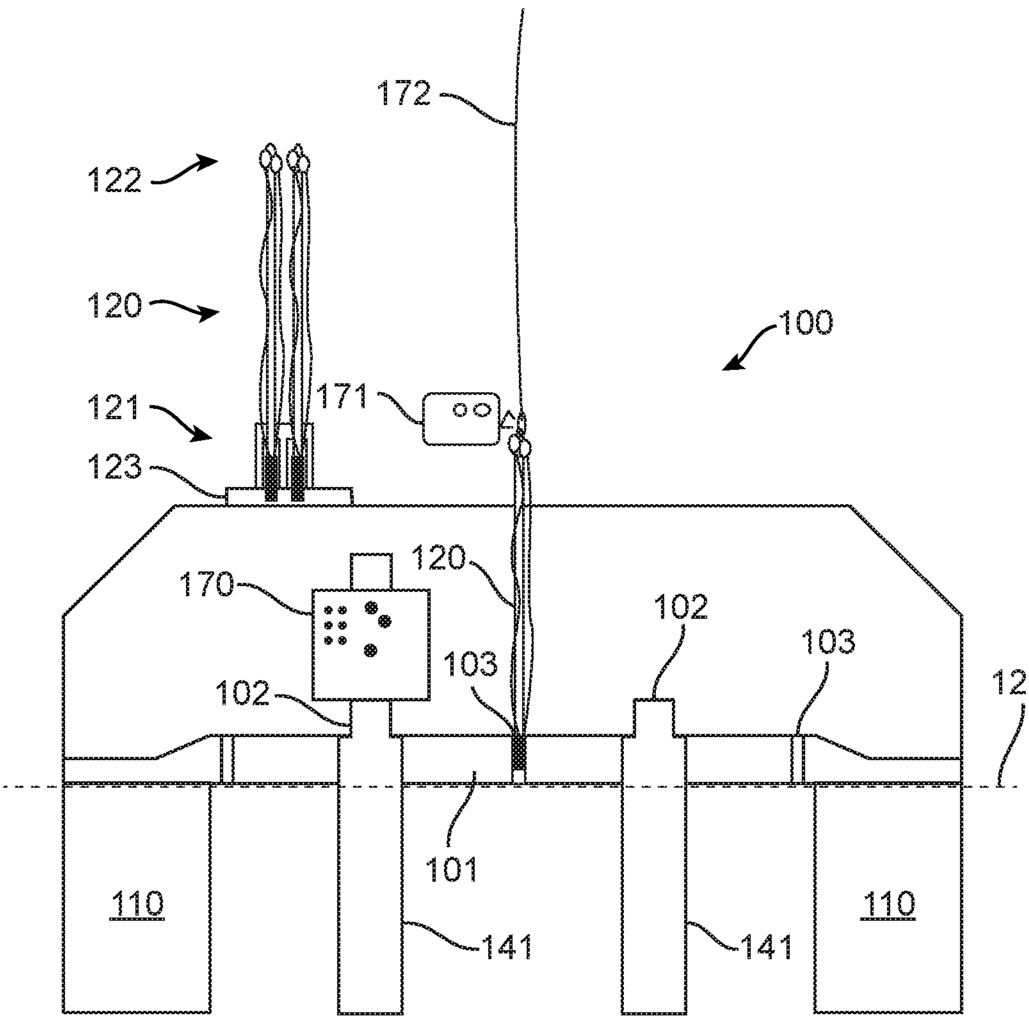

172
122
120
100
121
171
123
120
170
102
103
102
103
127
101
110
141
141
110

FIG. 2

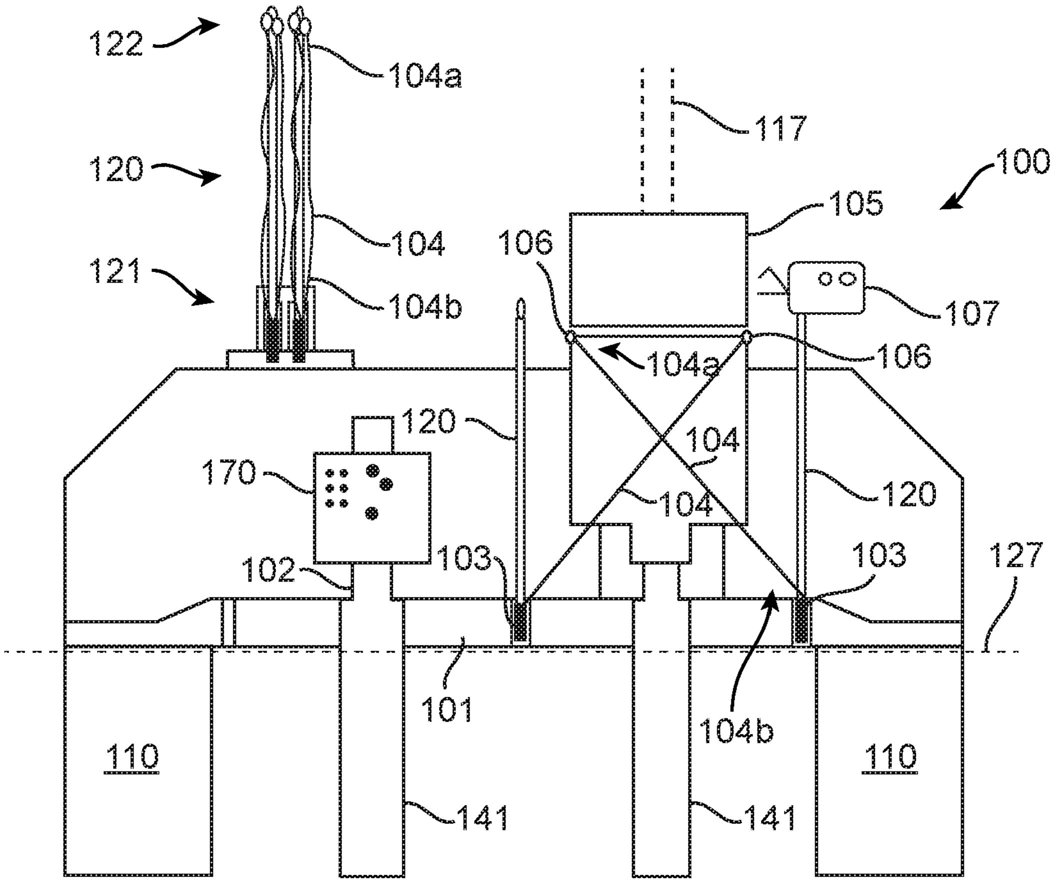

122
104a
120
104
121
104b
117
100
105
106
107
106
104a
120
104
170
104
120
102
103
103
127
101
104b
110
110
141
141

FIG. 3

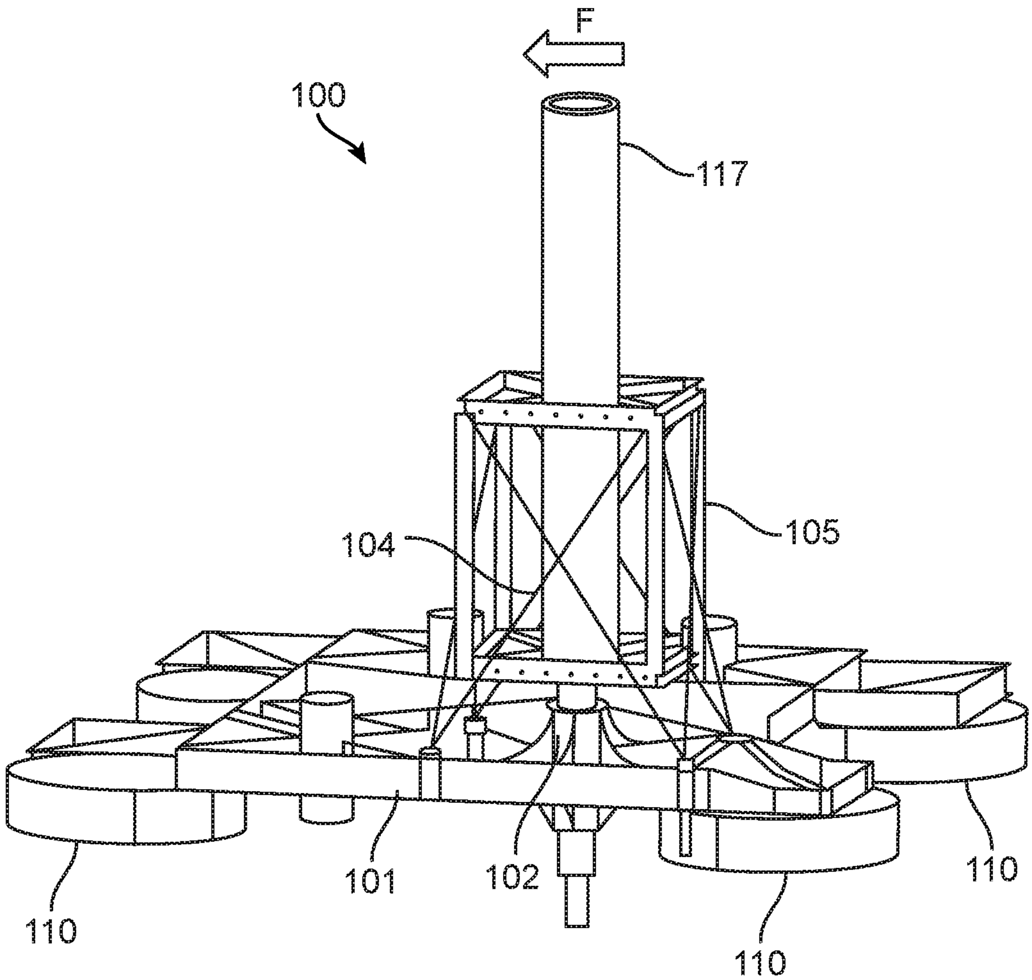



FIG. 4

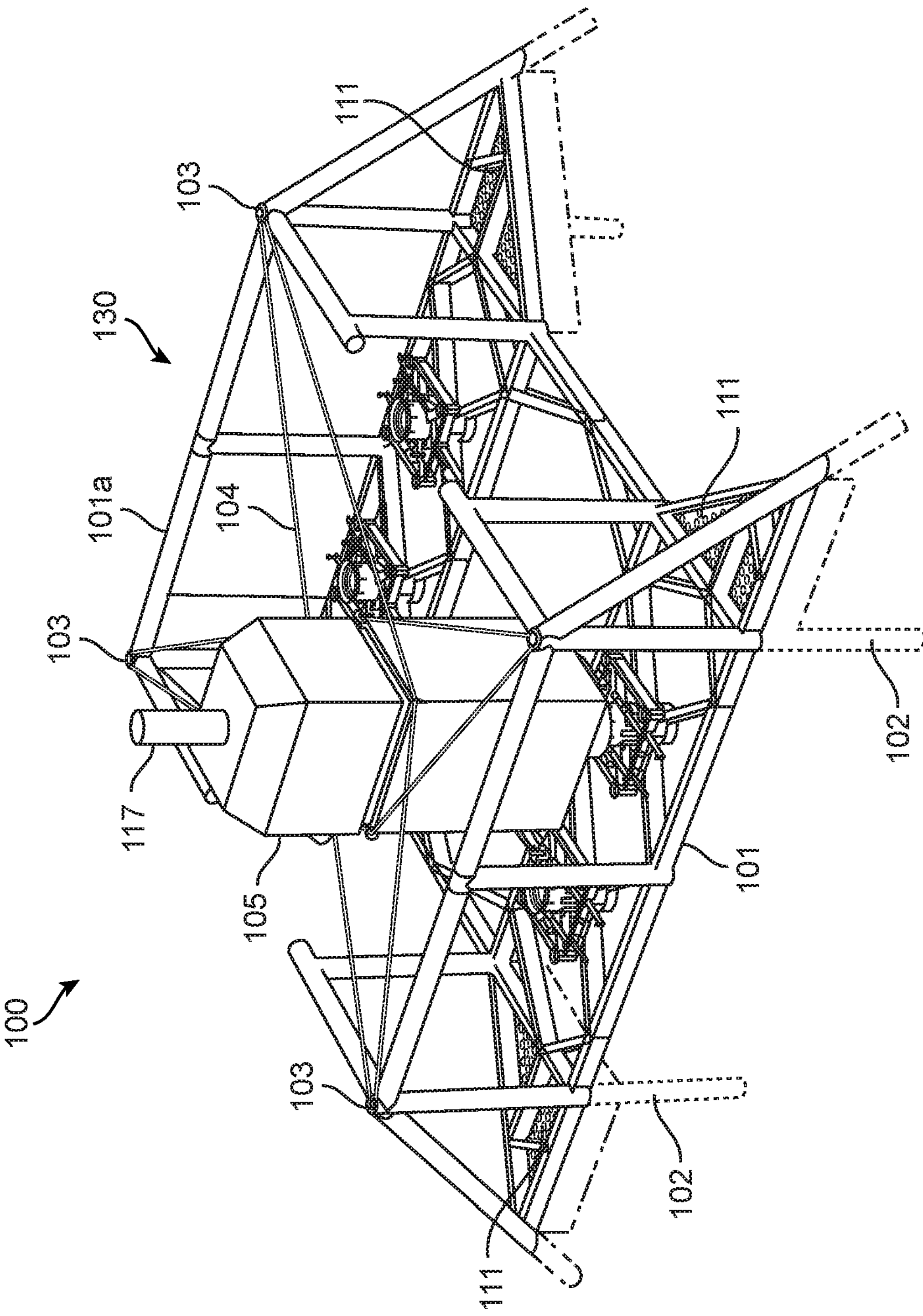



FIG. 5

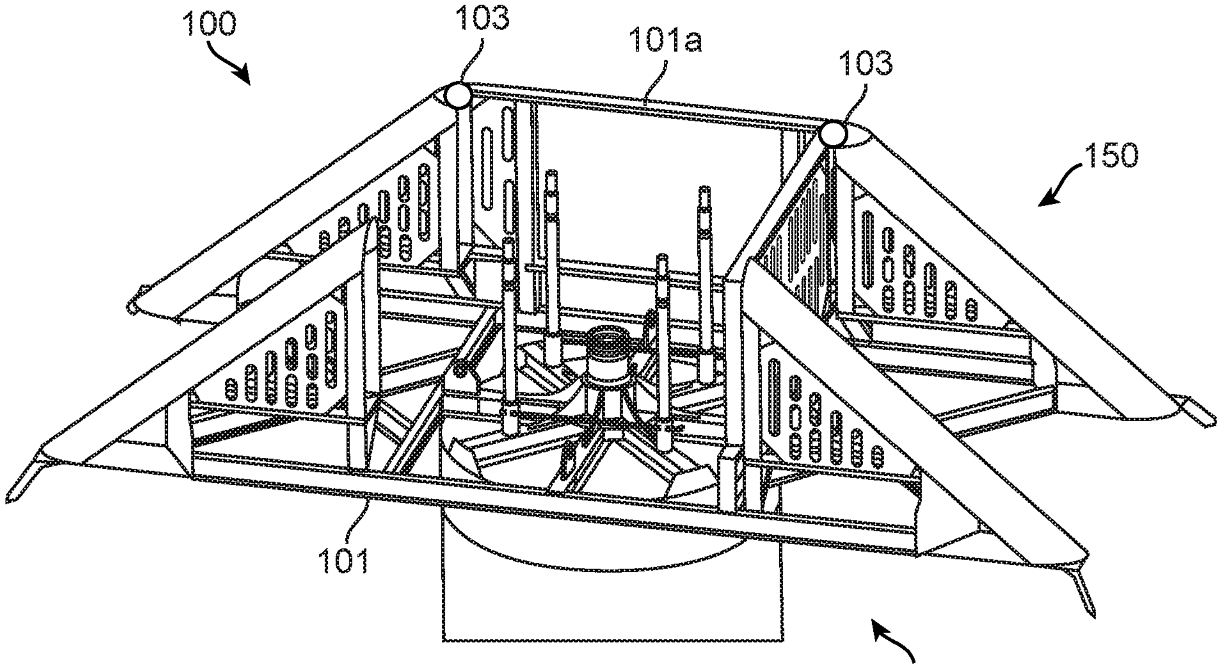

100
103
101a
103
150
101
140

FIG. 6

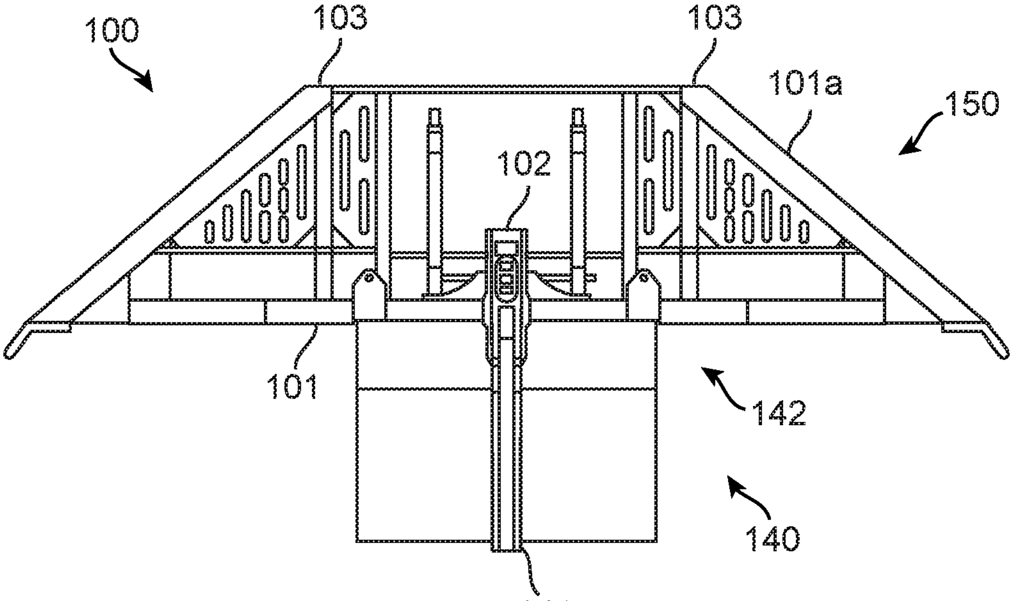

100
103
103
101a
150
102
101
142
140
141

FIG. 7

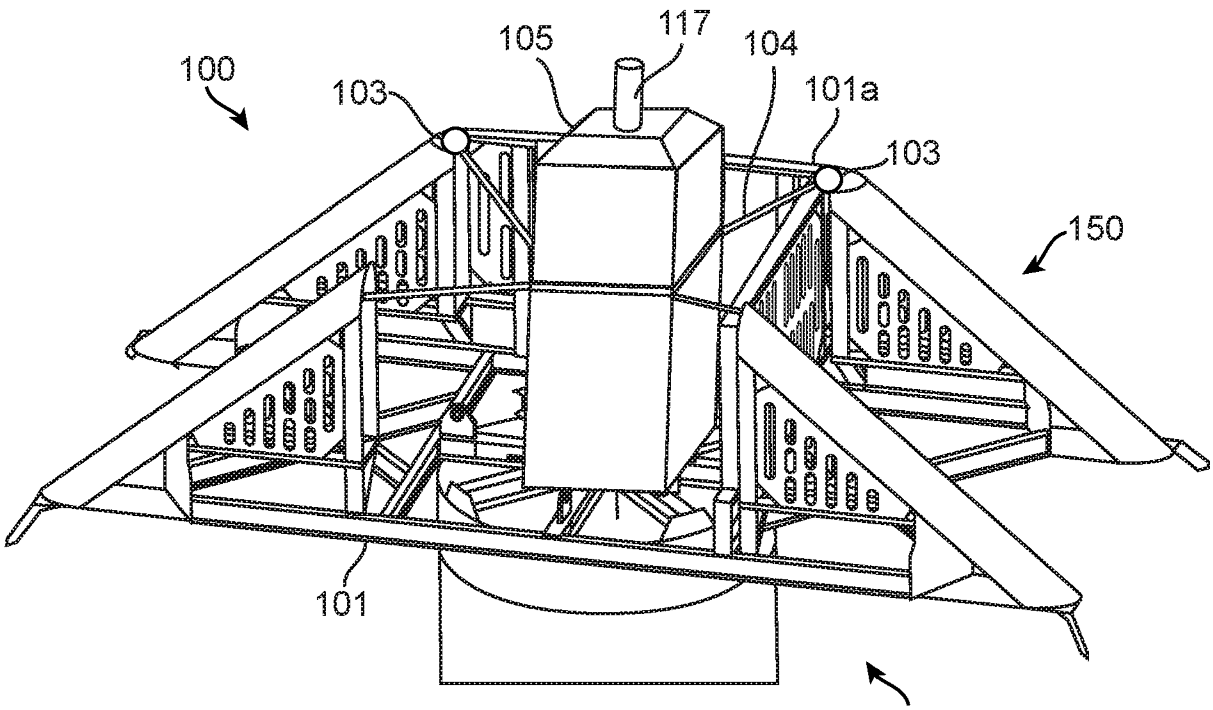



FIG. 8

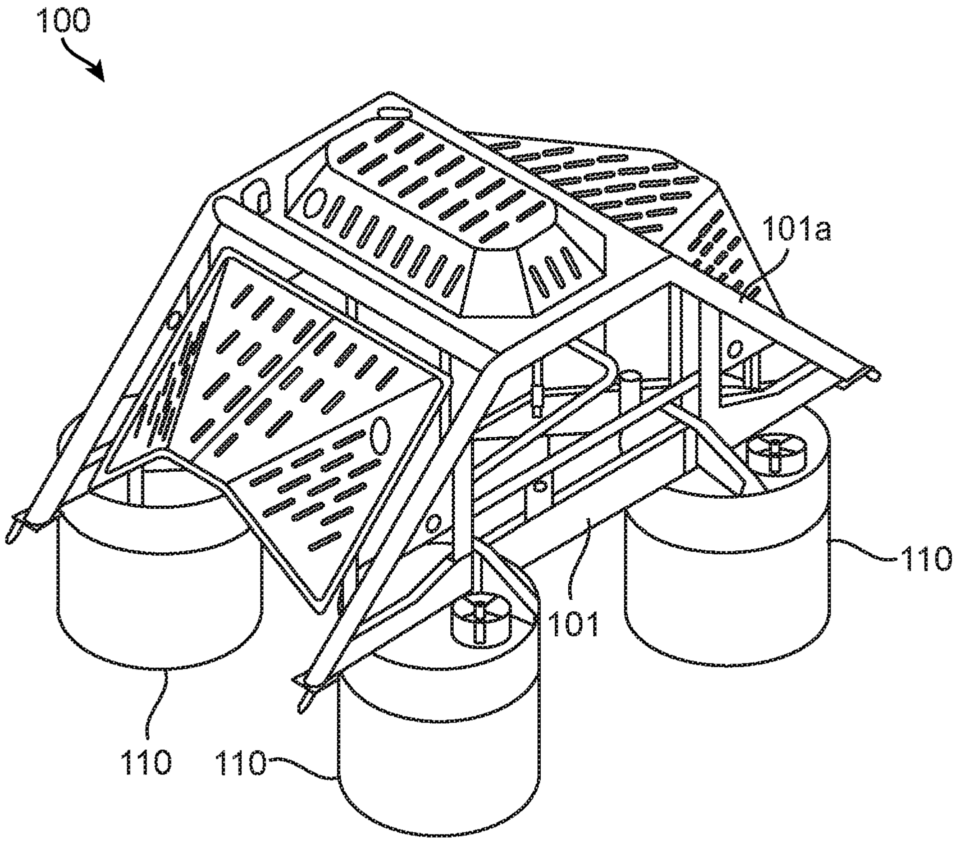



FIG. 9

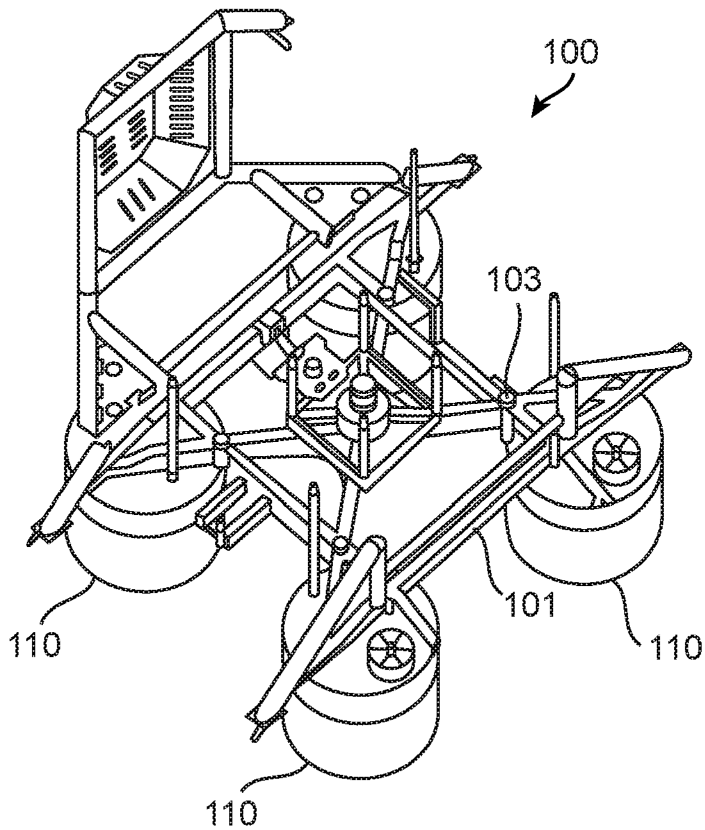



FIG. 10

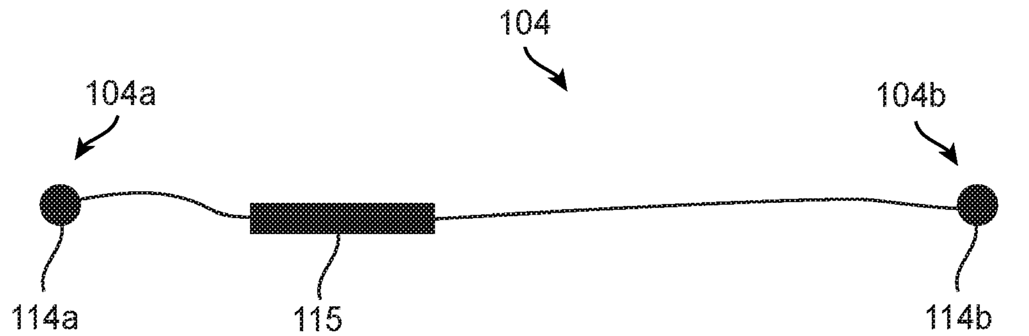

104
104a
104b
114a
115
114b

FIG. 11

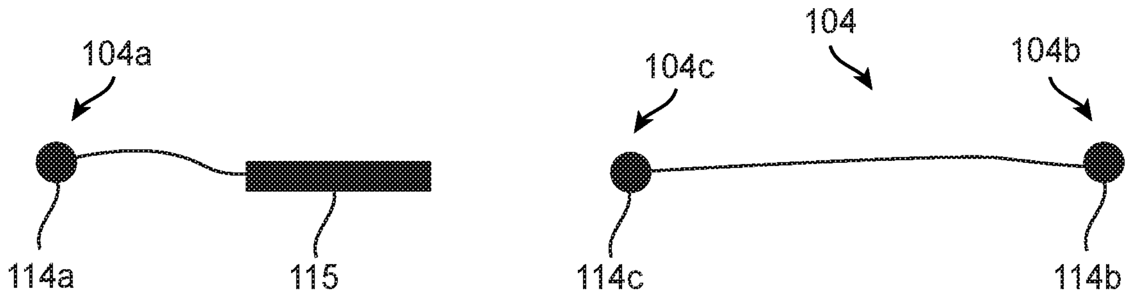

104a
104c
104
104b
114a
115
114c
114b

FIG. 12

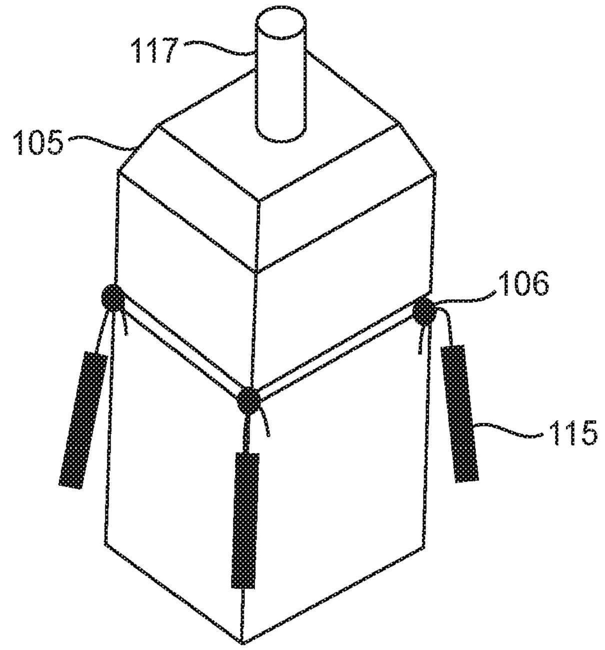



FIG. 13

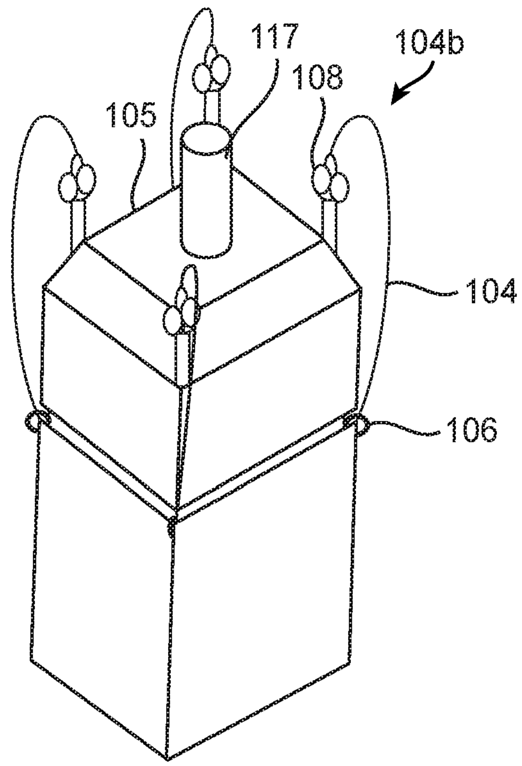



FIG. 14

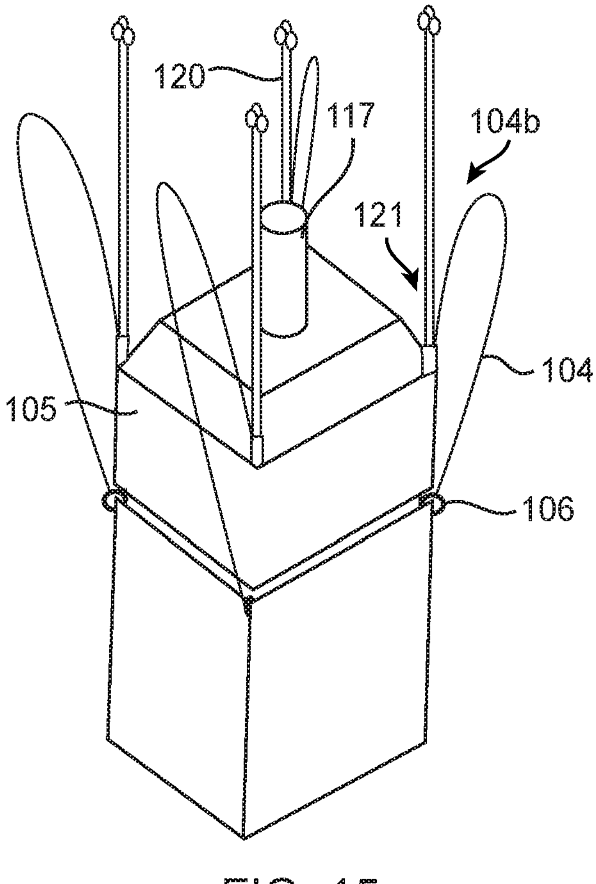



FIG. 15

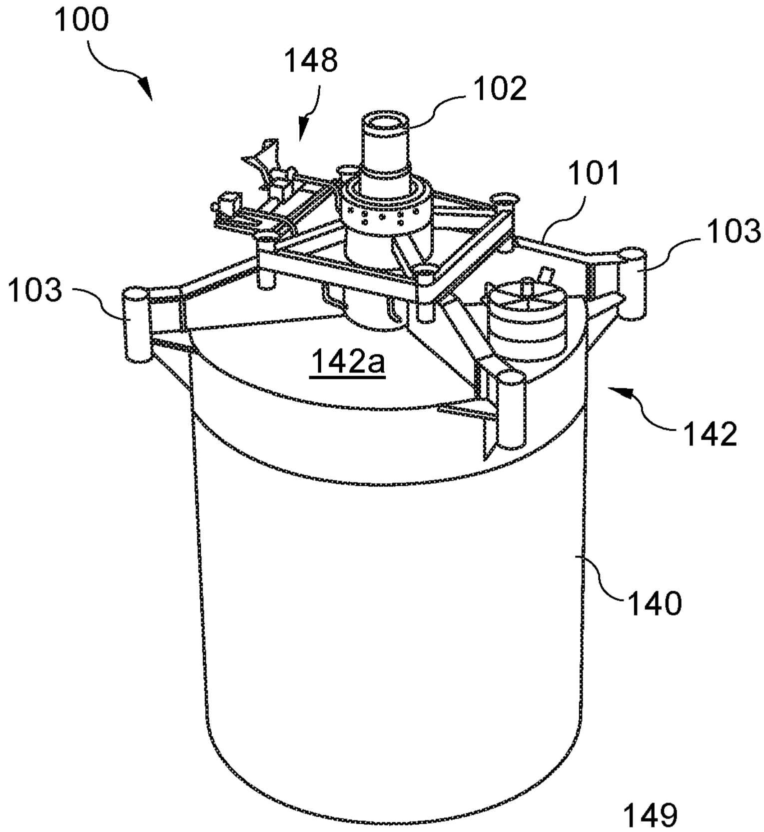



FIG. 16

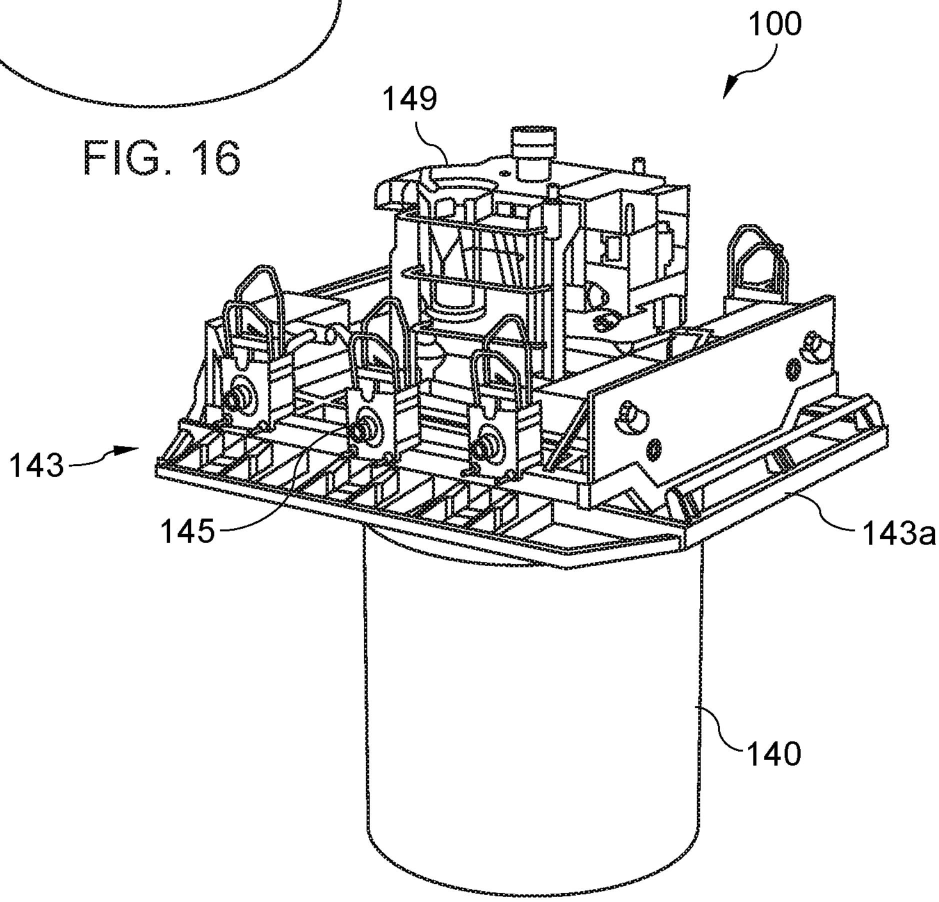



FIG. 17

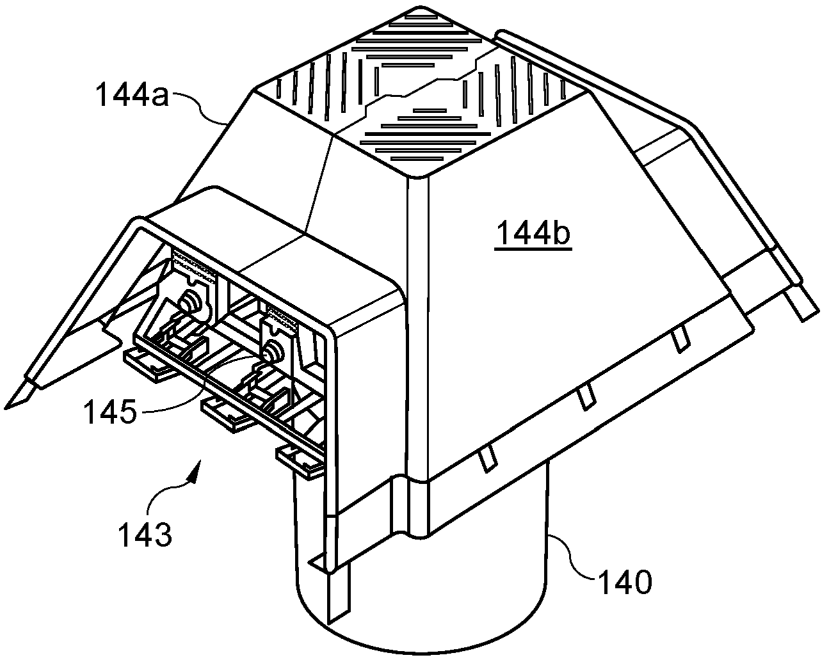



FIG. 18

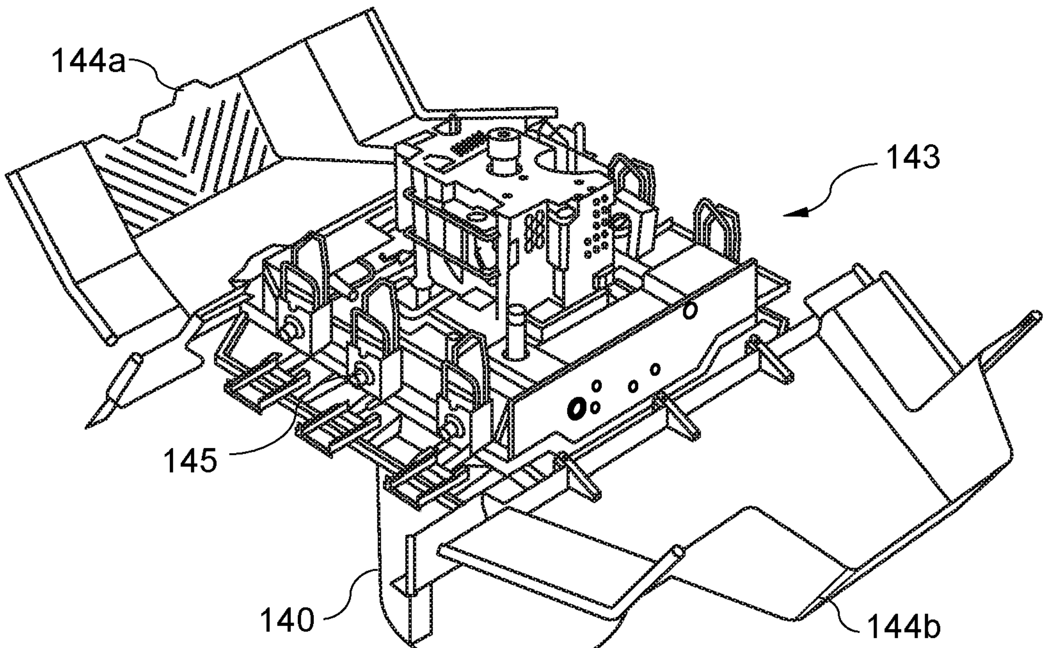



FIG. 19

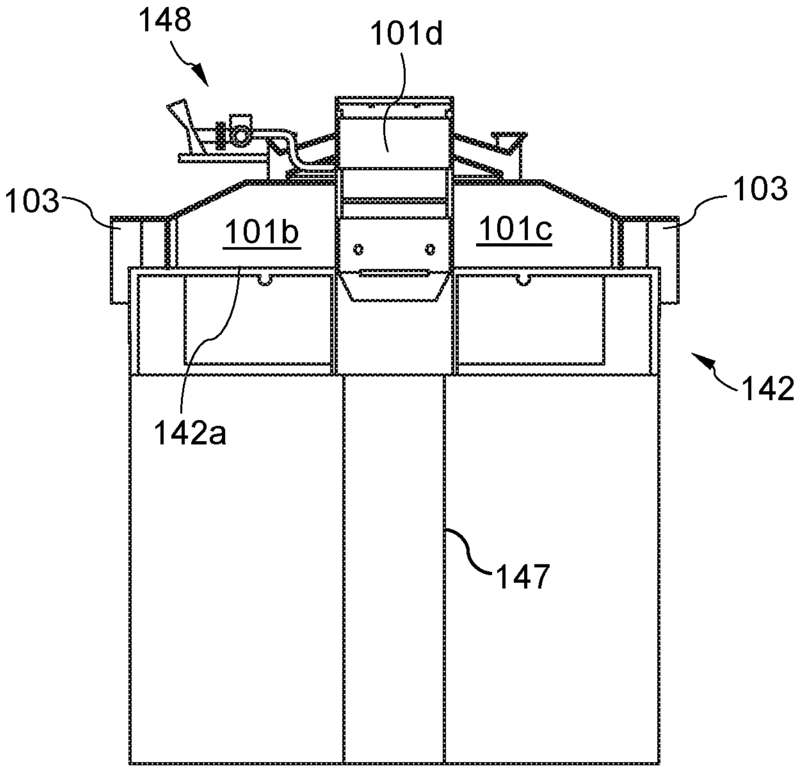

148
101d
103
101b
101c
103
142
142a
147

FIG. 20

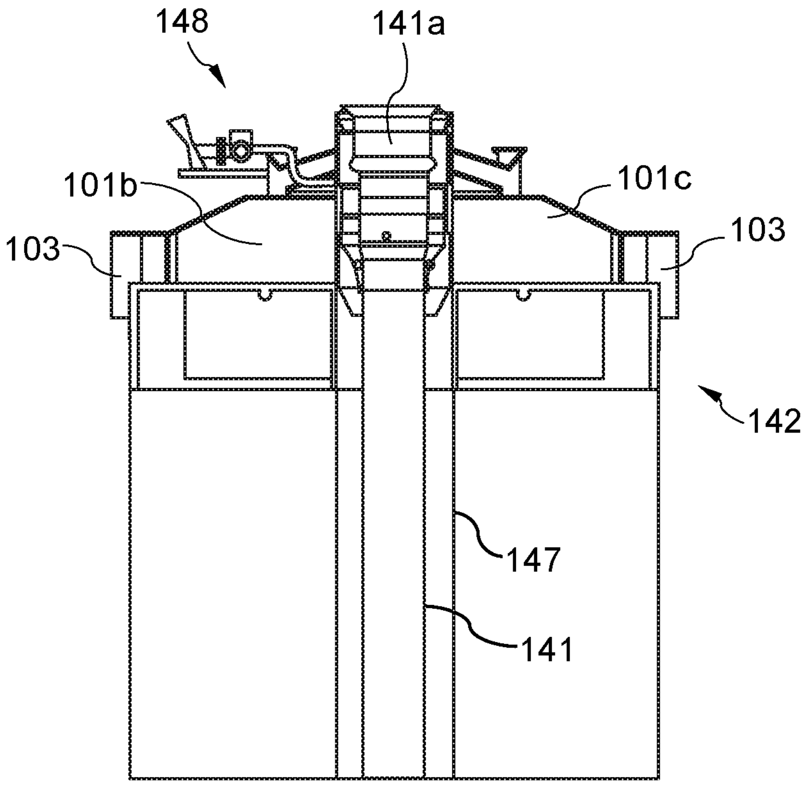

148
141a
101b
101c
103
103
142
147
141

FIG. 21

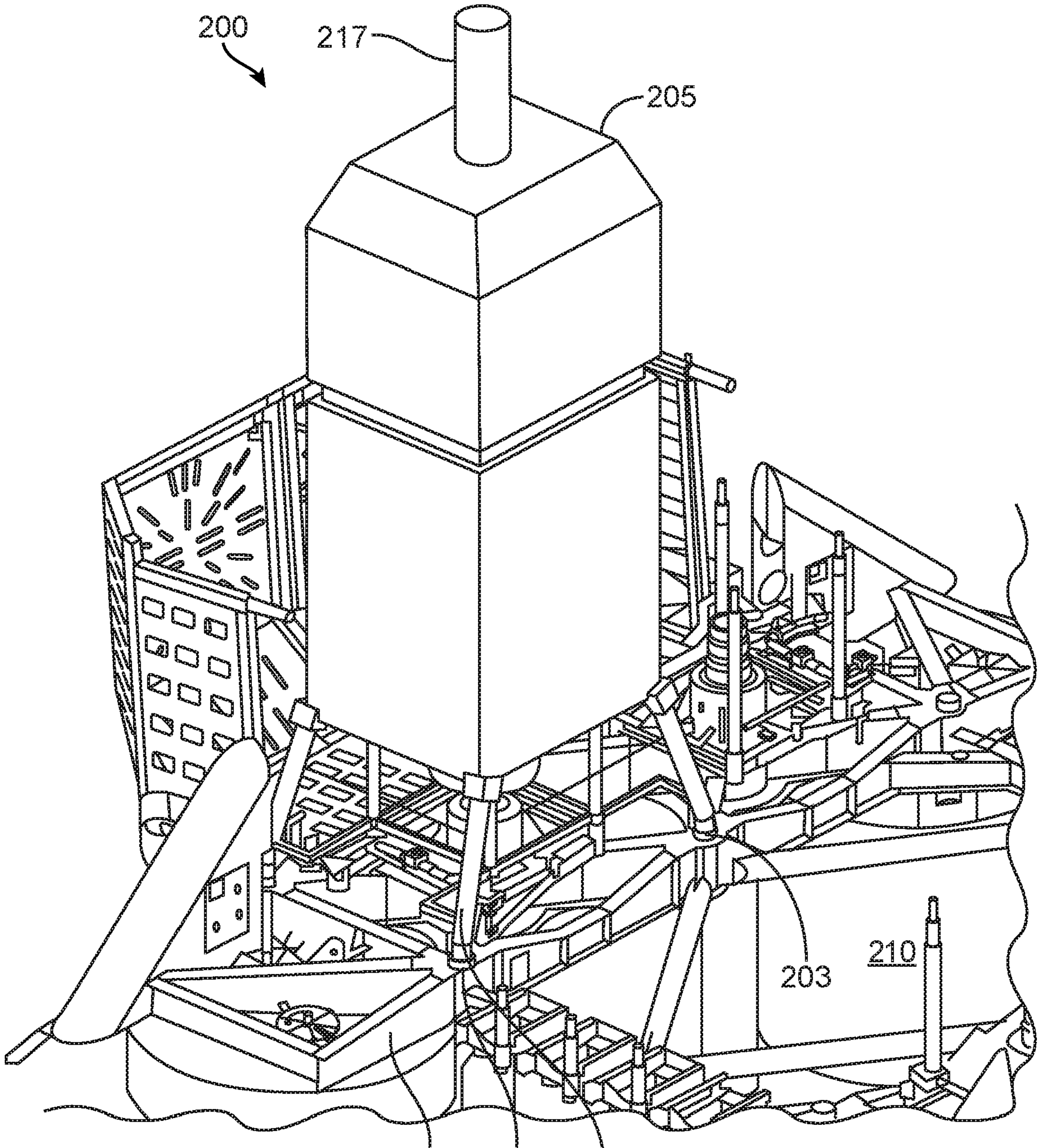



FIG. 22

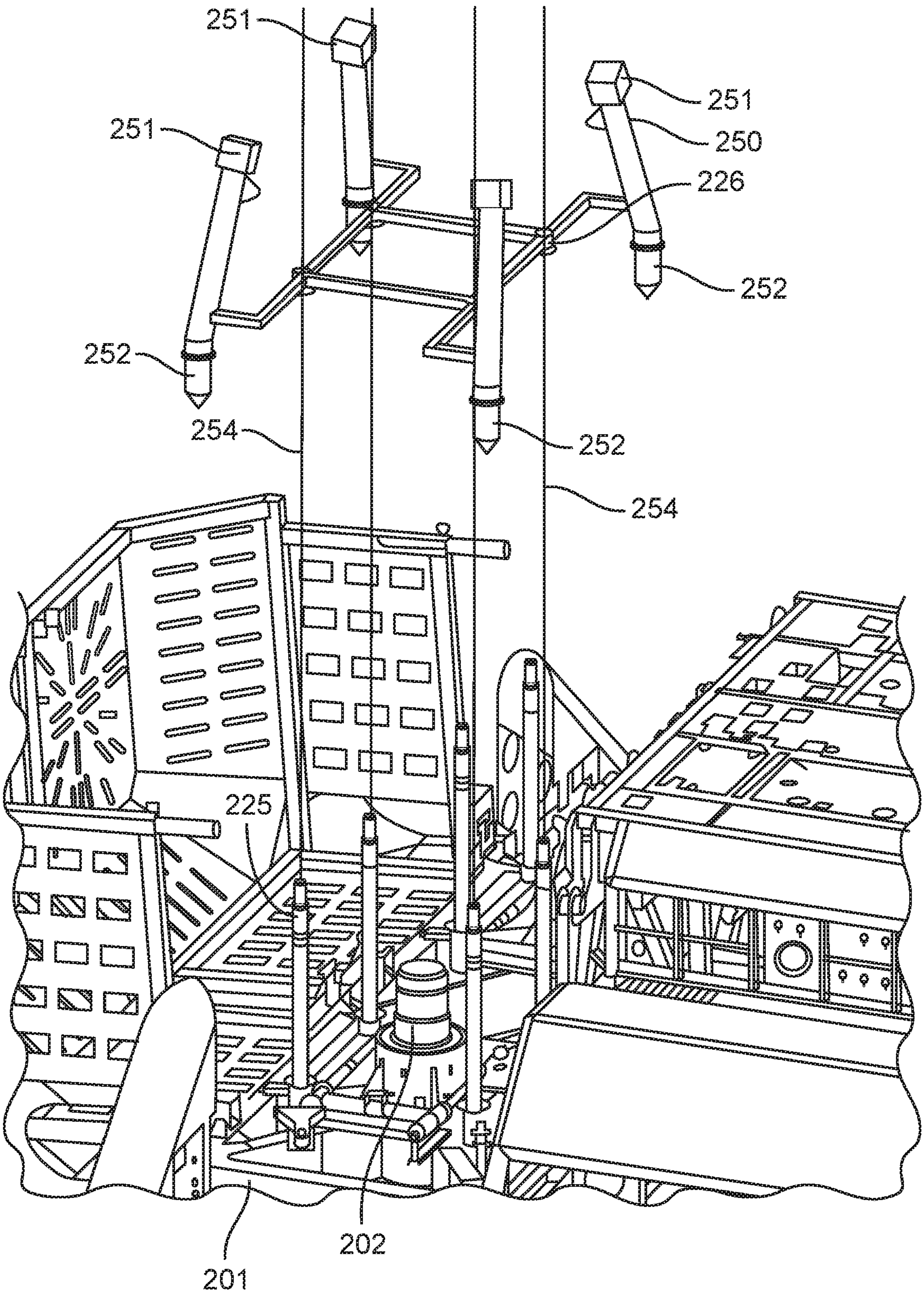



FIG. 23

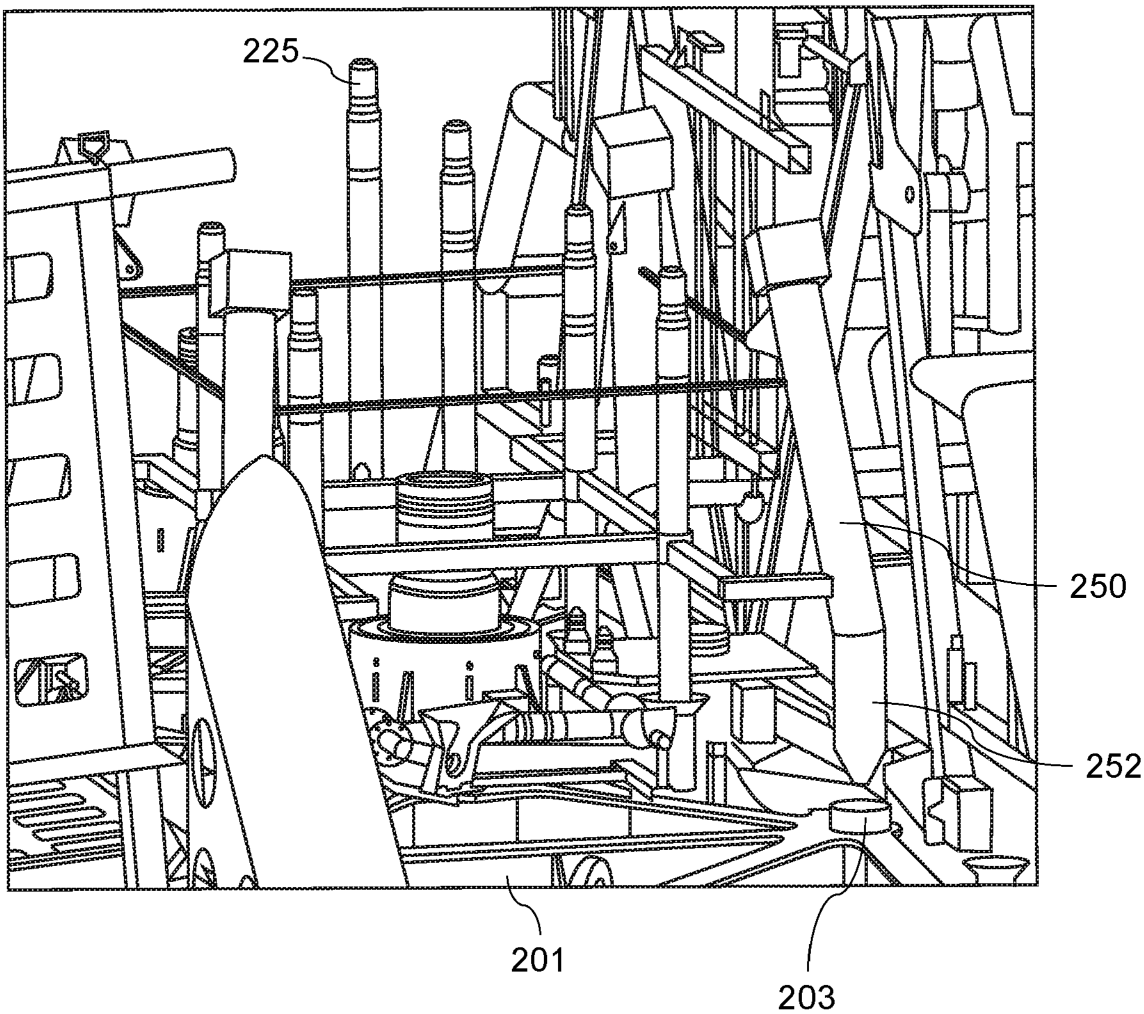



FIG. 24

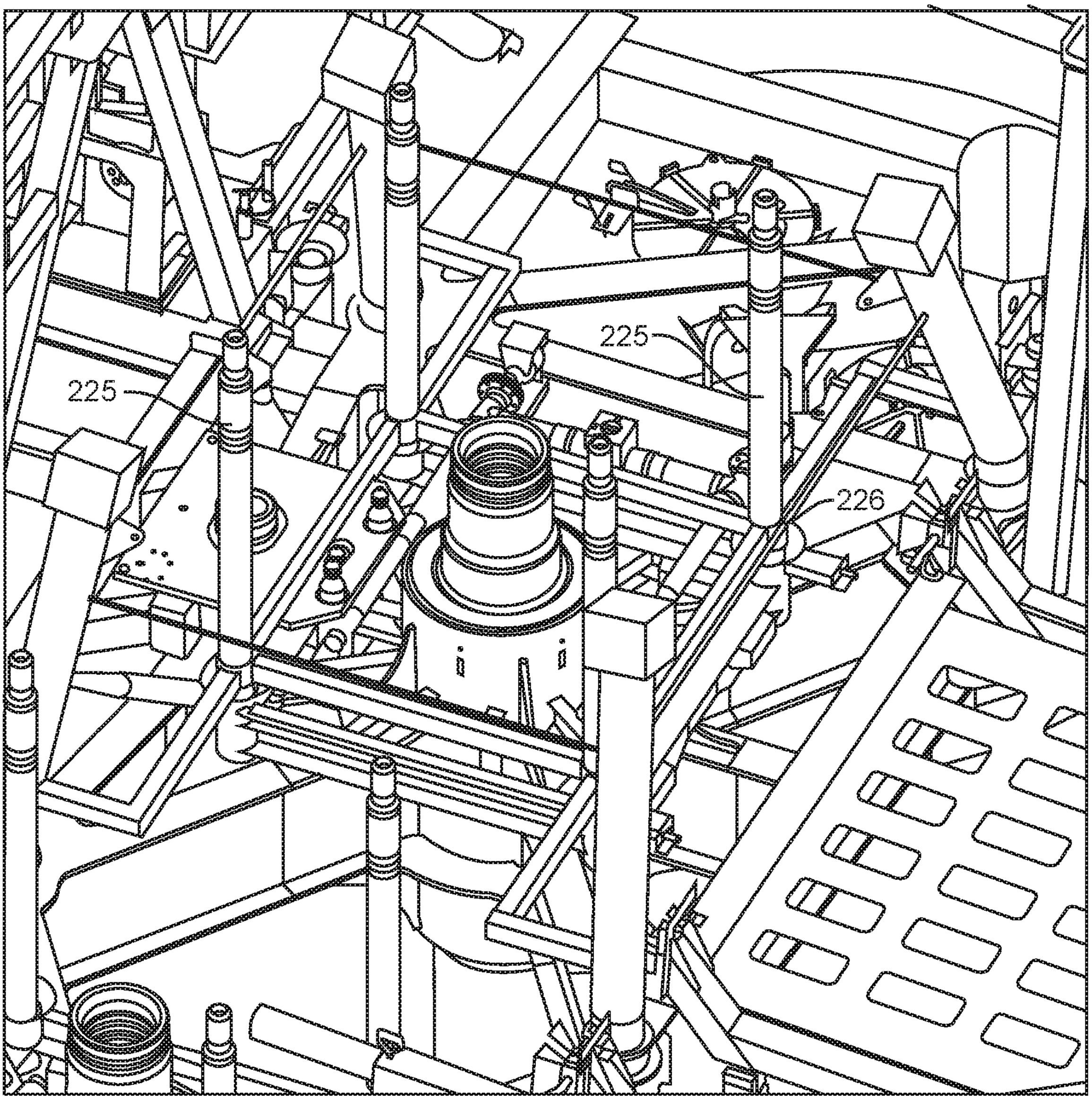



FIG. 25

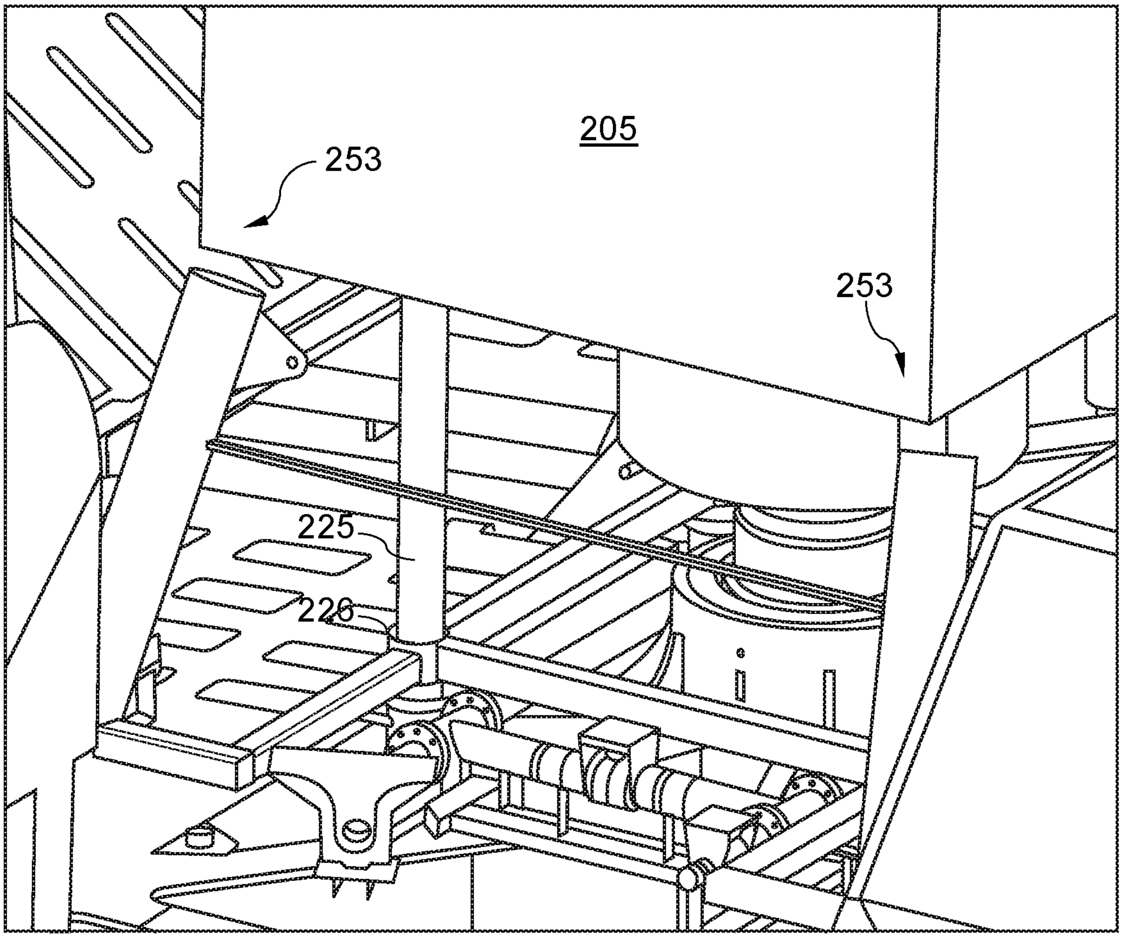



FIG. 26

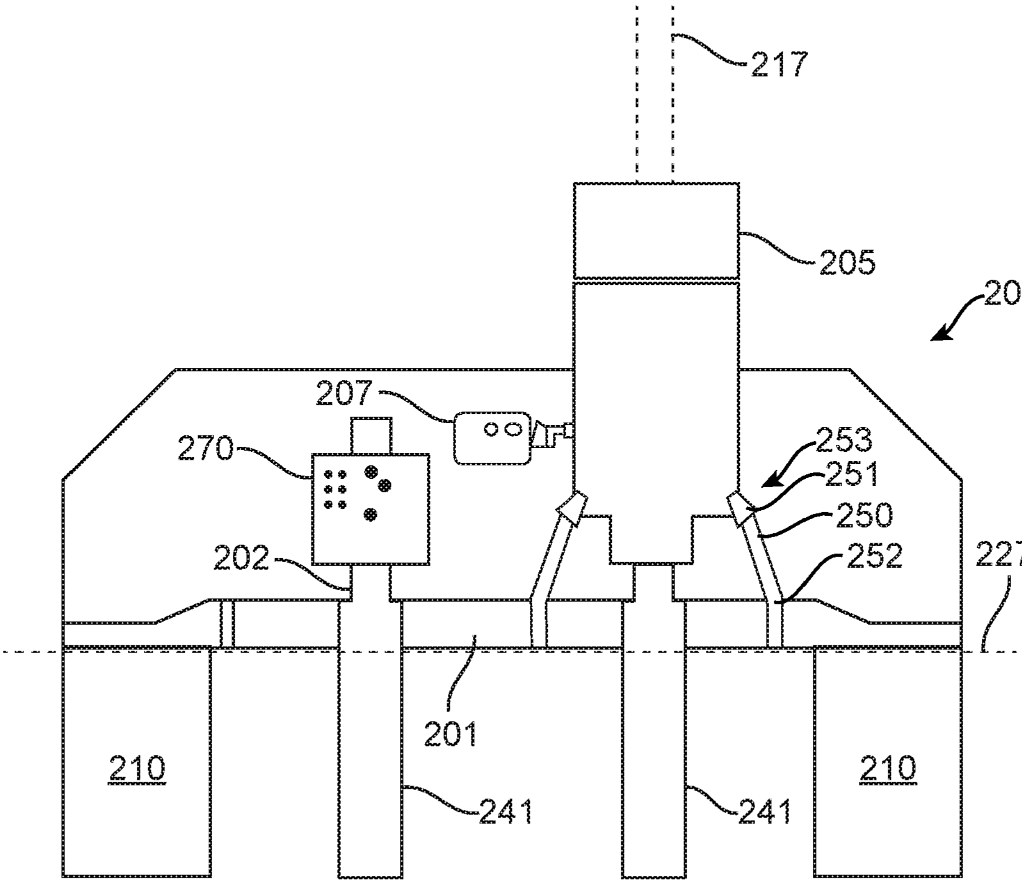



FIG. 27

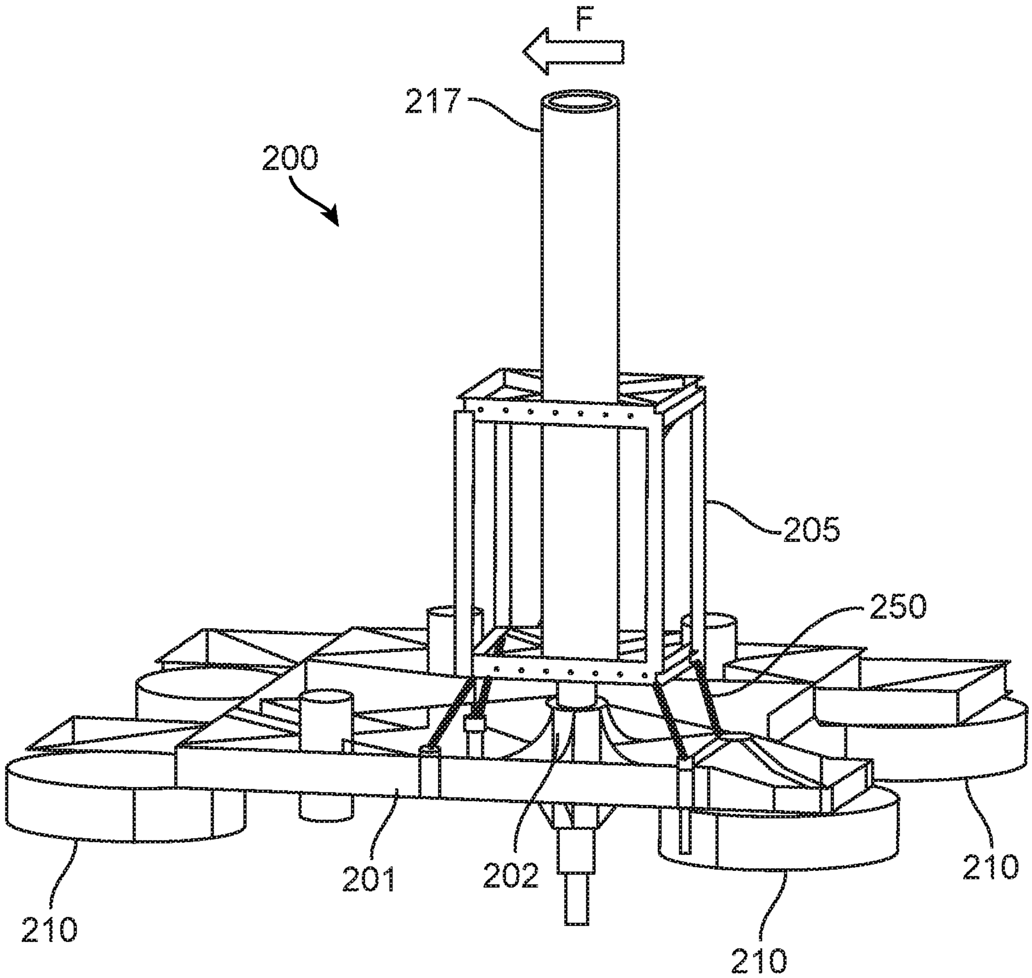



FIG. 28

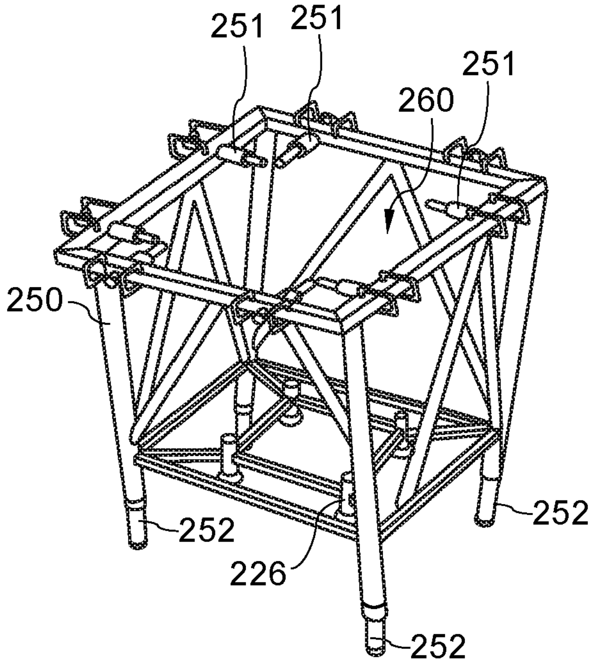

251
251
251
260
250
252
252
226
252

FIG. 29

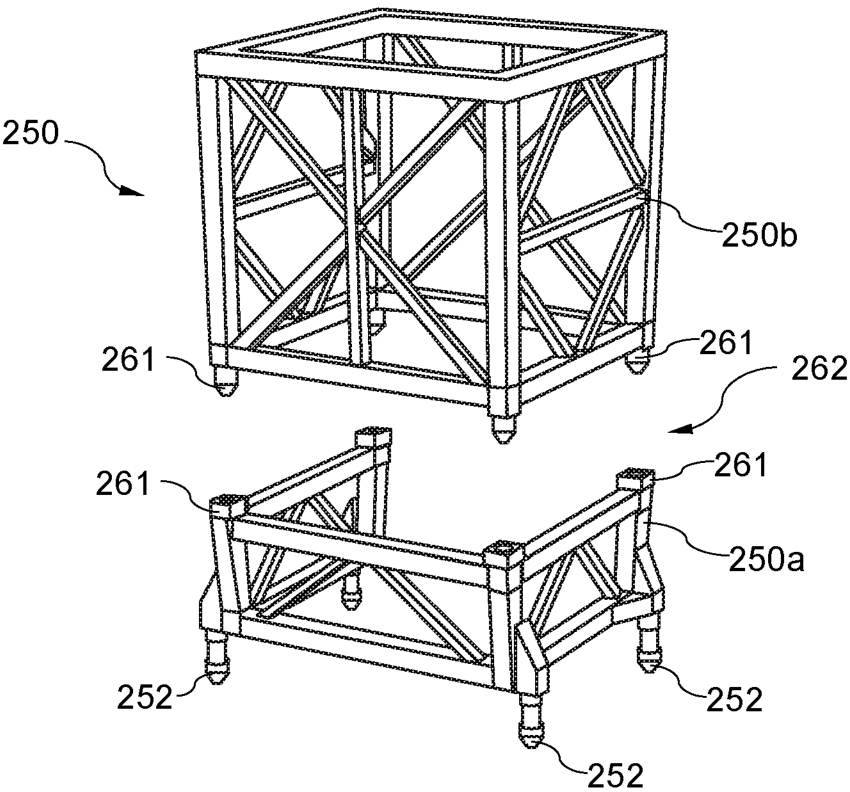

250
250b
261
261
262
261
261
250a
252
252
252

FIG. 30

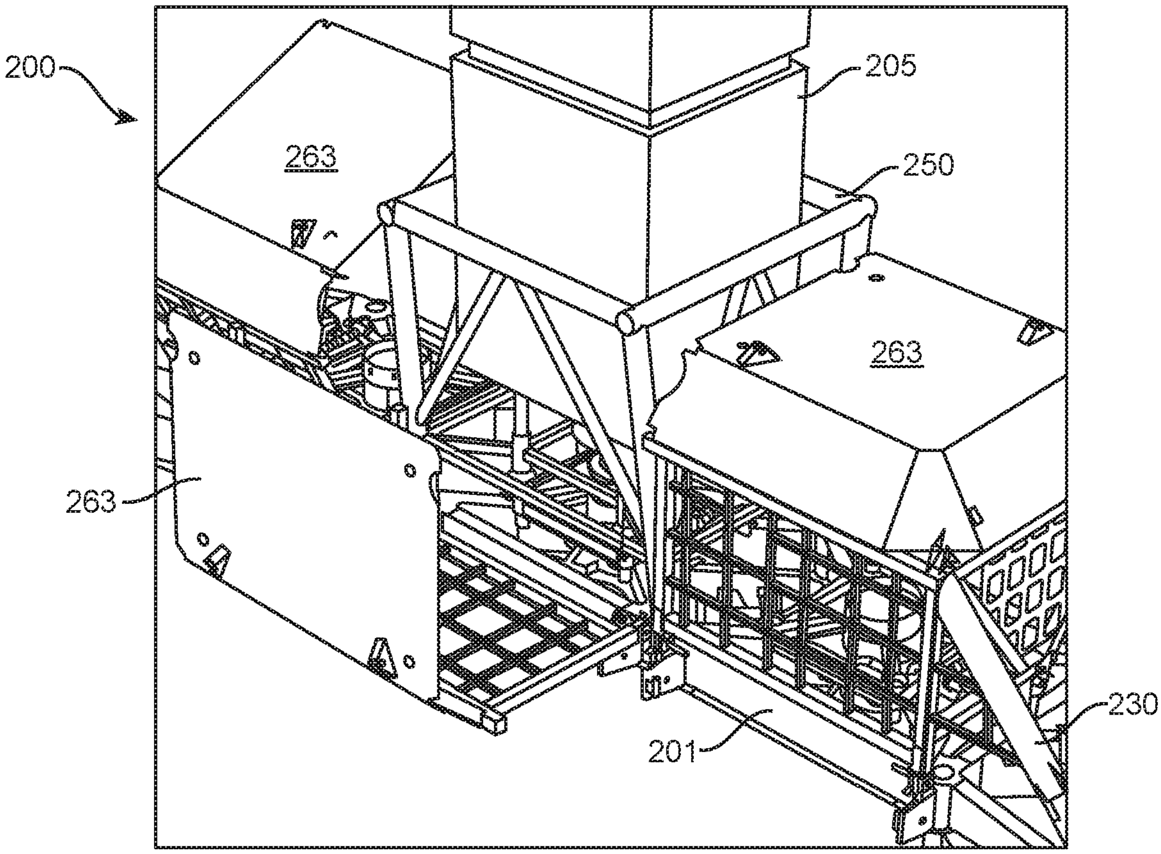

200
205
263
250
263
263
230
201

FIG. 31

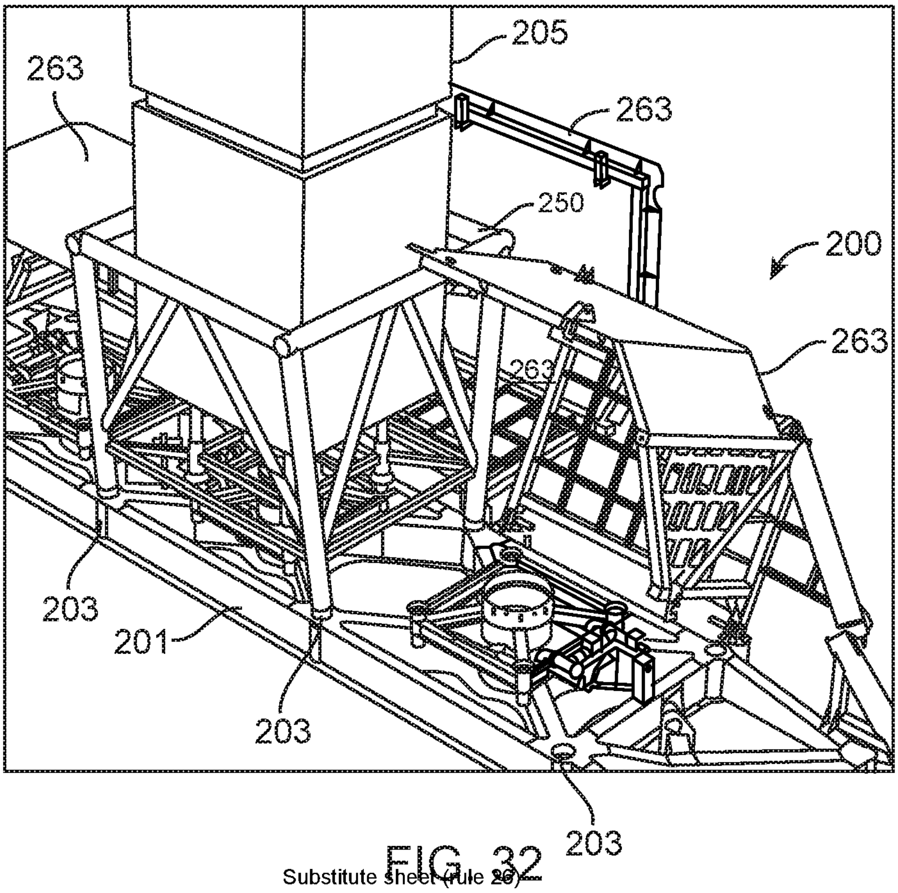

263
205
263
250
200
263
263
203
201
203
203

FIG. 32

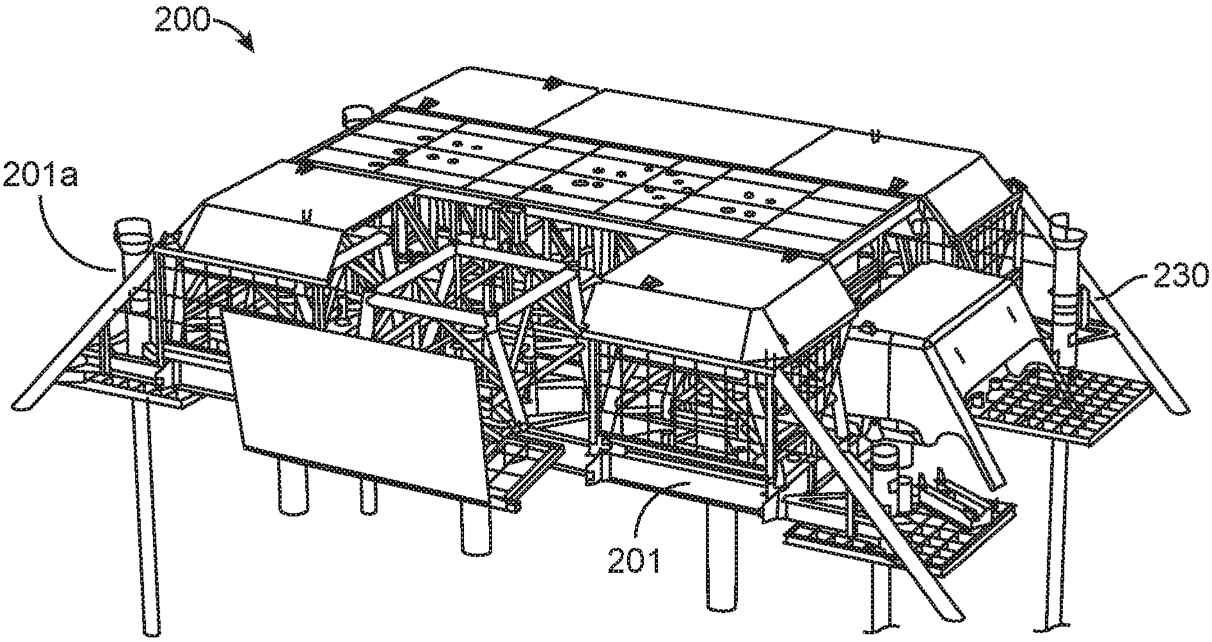



FIG. 33

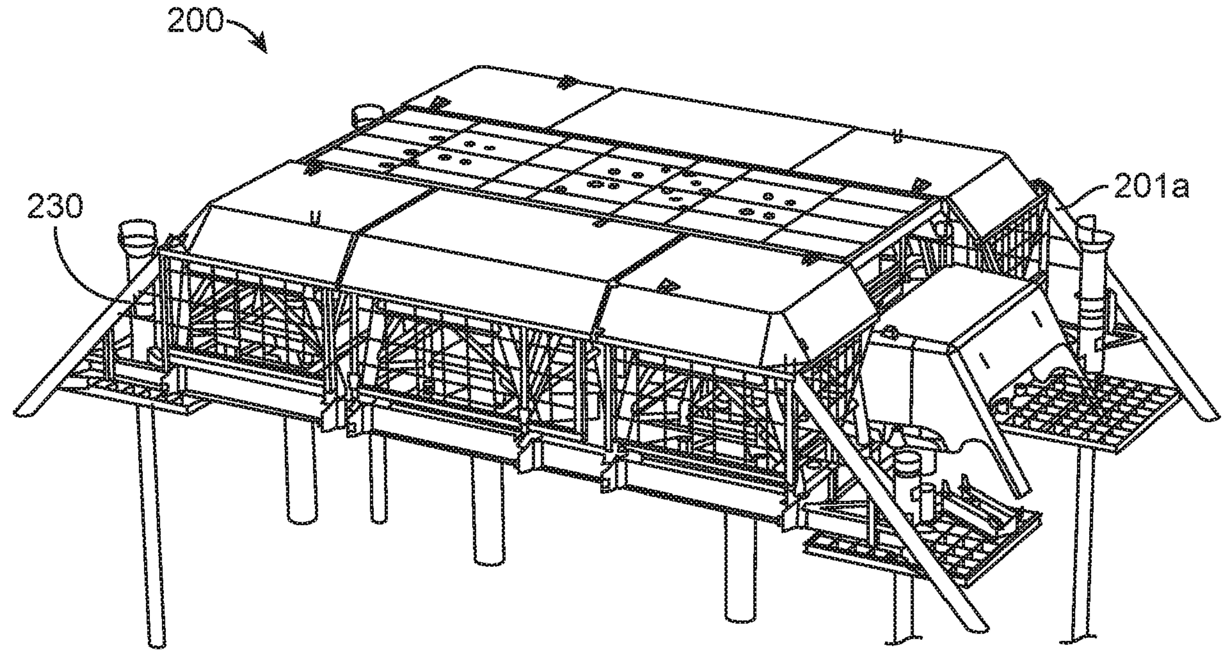



FIG. 34

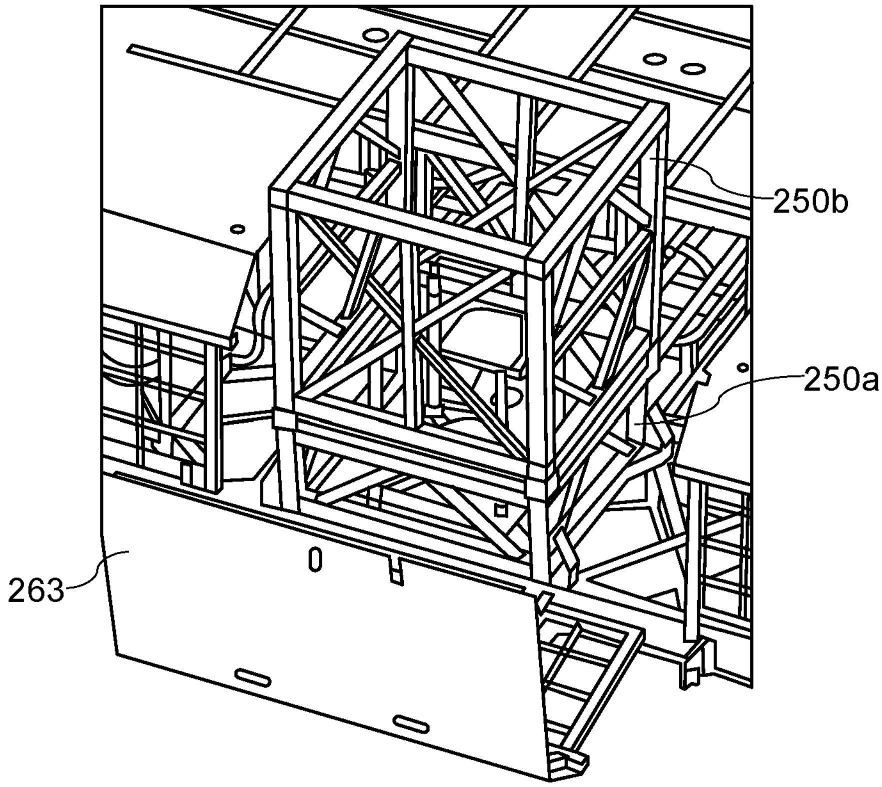



FIG. 35

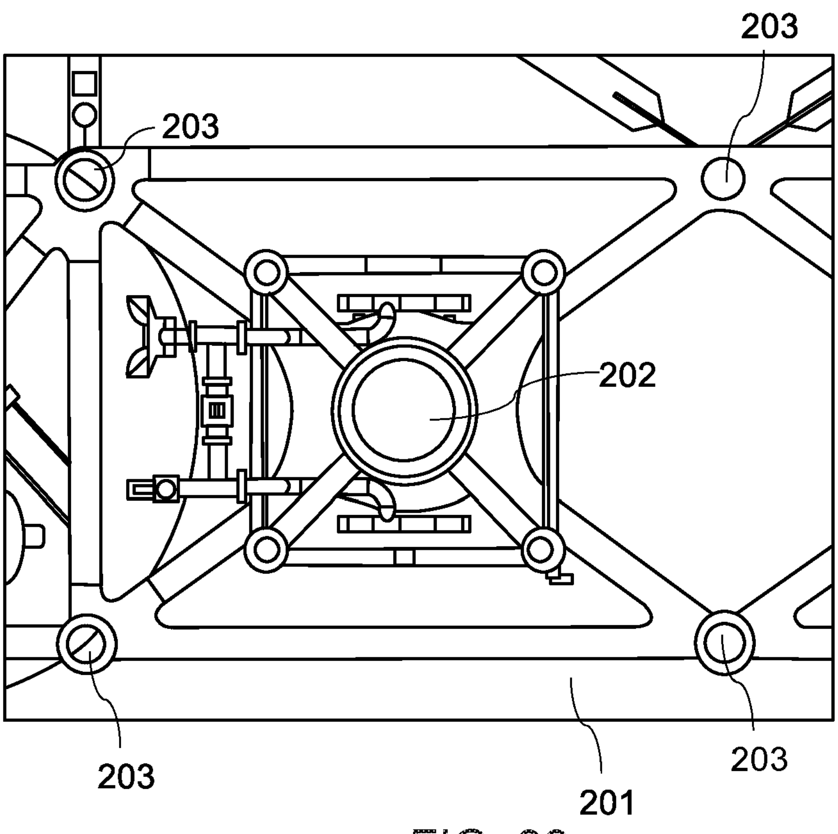



FIG. 36

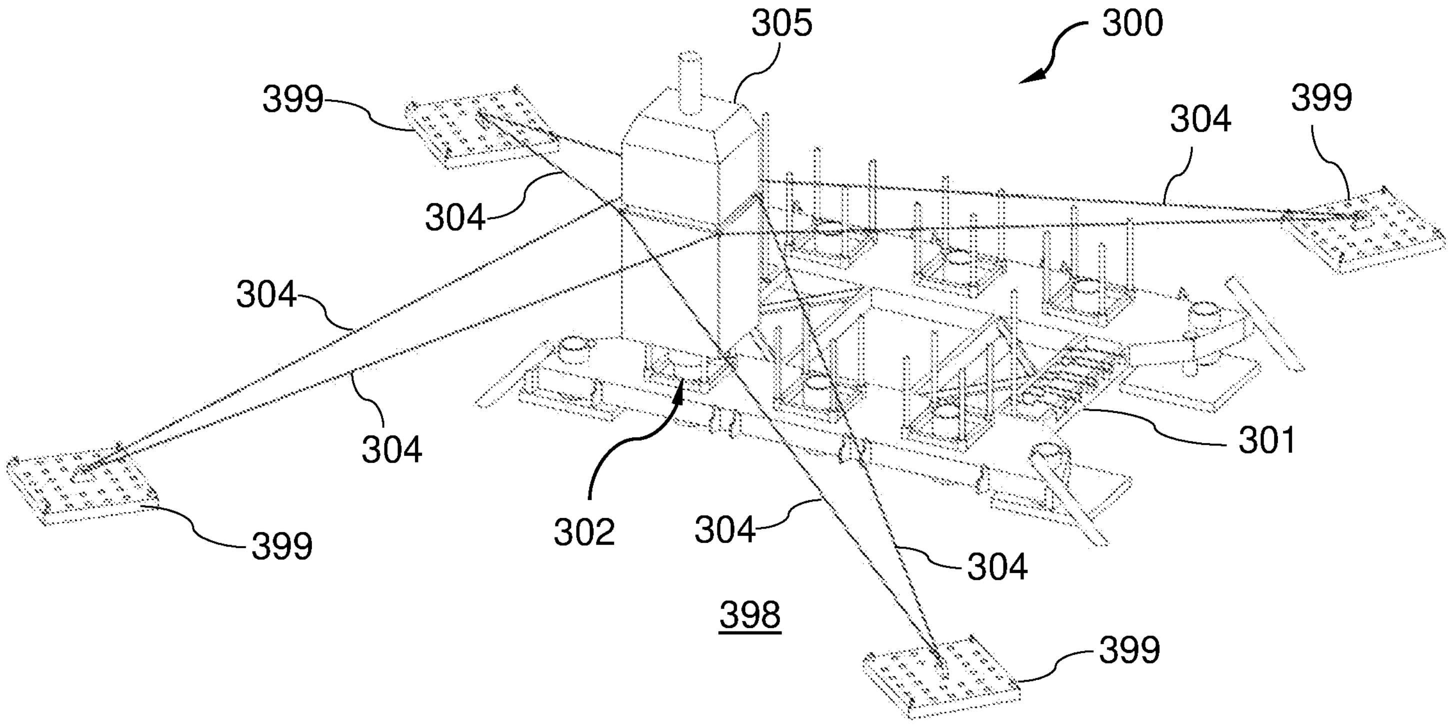



FIG. 37

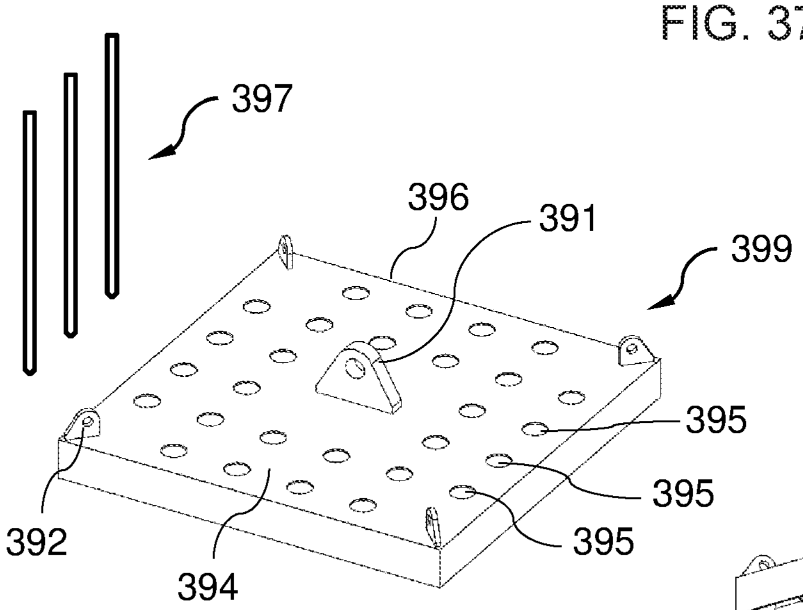



FIG. 38

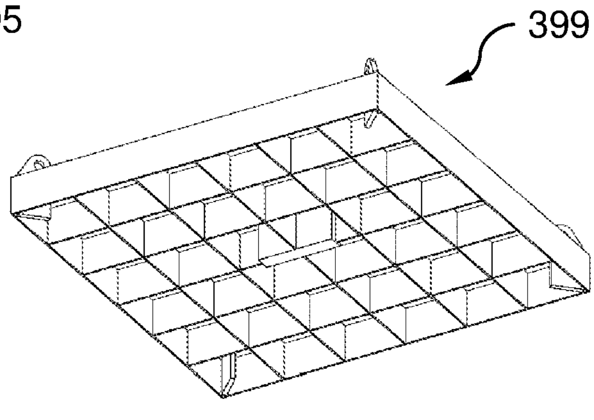



FIG. 39