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(54) **STABILIZATION METHODS AND SYSTEM**

(57) There is disclosed a method of stabilizing and/or lifting and/or separating a first structure (600) relative to a second structure, the method comprising the steps of: determining a volume of fluid required to inflate an inflatable element (630) disposed in a gap between the first and second structures to a first pressure level; based on the volume of fluid required and characteristics of the inflatable element (630), determining a second pressure level required to provide a desired stabilizing and/or lifting and/or separating force to be applied to the structures by the inflatable element (630); and further inflating the inflatable element (630) to the second pressure level.

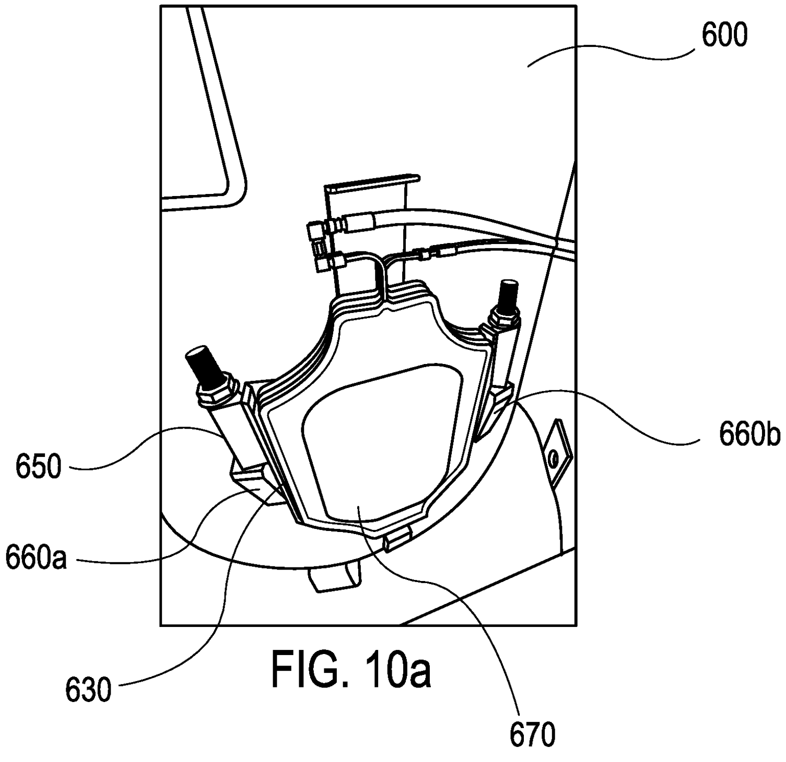

FIG. 10a

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Description

FIELD OF INVENTION

[0001] The present invention relates to methods of stabilizing and/or lifting and/or separating a first structure relative to a second structure, an associated system, and a method of installation. The methods and system may find utility offshore and/or in a marine environment.

BACKGROUND TO INVENTION

[0002] Offshore structures, such as offshore wind turbines, may be supported and/or mounted by a support structure, such as for example a jacket. The jacket may typically have three or four legs, which may be arranged to form a lattice structure. Jackets can be lowered onto pre-installed piles. The piles may be installed by driving them into the seabed using a piling hammer and/or a piling template.

[0003] Once the jacket has been lowered onto the piles, the jacket may be permanently fixed to the piles, for example, by forming a cemented or grouted connection between the jacket and the piles. The cemented or grouted connection may transfer loads between the jacket and the piles.

[0004] It is desirable to minimise or prevent any movement between the jacket and piles, until the cement or grout is fully cured so as to form a strong and robust connection between the jacket and the piles. This is often achieved by waiting for sufficiently calm weather conditions, which may lead to increased costs for installing the jackets on the piles.

[0005] Subsea packers and/or grippers may be used in the offshore industry for stabilizing or securing a support structure relative to a foundation, such as stabilizing a jacket relative to a pile, during installation. Such packers and/or grippers are described in UK Patent Application No. 1814224.0 (W3G Marine Ltd), which is hereby incorporated by reference in their entirety. Furthermore, such packers and/or grippers may find utility in other environments, such as in the construction industry for purposes of stabilizing, or lifting, e.g., jacking, a structure relative to another structure.

[0006] Installation of systems comprising such packers and/or grippers, in particular in offshore environments where visibility of the packers and/or grippers during installation and use may not be practicable, can be a complex operation. Such systems need to be reliable, both in terms of their installation and their usage. Furthermore, usage of such systems may require monitoring and assessment to ensure adequate and reliable stabilization and/or lifting is achieved, without incurring risks to personnel, excess costs ore requiring additional resources.

[0007] It is an object of at least one embodiment of at least one aspect of the present invention to obviate or at least mitigate one or more problems or disadvantages in the prior art.

SUMMARY OF INVENTION

[0008] According to a first aspect of the present invention there is provided a method of stabilizing and/or lifting and/or separating a first structure relative to a second structure. The method may comprise one or more of the steps of: determining a volume of fluid required to inflate an inflatable element disposed in a gap between the first and second structures to a first pressure level; based on the volume of fluid required and characteristics of the inflatable element, determining a second pressure level required to provide a desired stabilizing and/or lifting and/or separating force to be applied to the structures by the inflatable element; and (further) inflating the inflatable element to the second pressure level.

[0009] Advantageously, by basing a subsequent pressure/inflation level on a measured volume of fluid to provide a first pressure level, i.e. a first predetermined pressure level, stabilization and/or lifting and/or separating of the first structure relative to the second structure may be carried out without direct visibility of the structures and/or inflatable element(s). For example, when the first or second structure is a subsea pile and the other of the first and second structure is a jacket for an off-shore wind turbine, an inflatable element disposed between the first and second structure may be below sea-level, thus inhibiting visibility of the inflatable element. Thus, controlling a stabilizing and/or lifting and/or separating effect of the inflatable element by means of measuring a volume of fluid used to inflate the element, in addition to predetermined characteristic of the inflatable element, permits remote operation of the element, i.e. control of pressurisation and/or depressurization from surface.

[0010] The step of determining a second pressure level may further comprise determining a size of the gap based on the volume of fluid required and a first characteristic of the inflatable element.

[0011] The step of determining a second pressure level may further comprise making a determination of the second pressure level based on the determined size of the gap and a second characteristic of the inflatable element.

[0012] The step of further inflating the inflatable element to the second pressure level may comprises the step of initially inflating the inflatable element to a third pressure level, the third pressure level being substantially greater than the second pressure level. The step of further inflating the inflatable element to the second pressure level may comprises the step of subsequently deflating the inflatable element to the second pressure level.

[0013] Advantageously, by increasing the pressure level to a level substantially greater than a required level, e.g. by effectively initially overinflating/over pressurizing the inflatable element, a deformation of the inflatable element may be maximised. By maximizing the deformation of the inflatable element, a surface area of the inflatable element in contact with, and thus applying a force to, the first and/or second structure may be maximised.

[0014] The determination of the third pressure level may be based on the determined size of the gap and a third characteristic of the inflatable element.

[0015] The first characteristic may be a relationship between the size of the gap and a volume of fluid required to inflate the inflatable element to the first pressure level.

[0016] The second characteristic may be a relationship between the size of the gap and pressure level required to provide the desired stabilizing force and/or a force that incurs a required, or maximum, deformation of the inflatable element.

[0017] The third characteristic may be a relationship between the size of the gap and a pressure level required to provide the desired stabilizing force and/or a force that incurs a required, or maximum, deformation of the inflatable element.

[0018] The first and/or second and/or third characteristics may be predetermined characteristics.

[0019] The method may comprise the step of characterising the inflatable element by means of simulation and/or testing to determine the first and/or second and/or third characteristics.

[0020] Advantageously, such characterisation of the inflatable element may be carried out at low cost, and avoids a requirement for *in situ* testing of the inflatable element.

[0021] The method may comprise the step of characterising a further inflatable element equivalent, similar or comparable to the inflatable element, by means of simulation and/or testing to determine the first and/or second and/or third characteristics.

[0022] Advantageously, costs and resource requirements may be minimised by performing characterisation in an off-line and typically on-shore situation, and/or by using a lower-cost equivalent of the inflatable element used in practice.

[0023] The method may comprise the step of disposing the at least one inflatable element in the gap between the first and second structures. The at least one inflatable element may be disposed on the first or second structures prior to the first and second structures being disposed relative to each other to form the gap.

[0024] The method may further comprise the step of testing the integrity of the inflatable element. Testing the integrity of the inflatable element may comprise decreasing the pressure in the inflatable element to a pressure level below a default pressure. Testing the integrity of the inflatable element further comprise assessing, e.g. subsequently assessing, whether the pressure level below the default pressure is sustained after a period of time.

[0025] Advantageously, such an integrity test avoids excessively deforming the inflatable elements prior to use. By avoiding excessive deformation, if can be ensured that the first structure can be disposed relative to the second structure without interfering with, e.g. damaging, the inflatable element.

[0026] The determination of the volume of fluid required to inflate the inflatable element may be made or performed using a flow meter. The flow meter may be communicably coupled to the inflatable element.

[0027] A determination of a pressure level in the inflatable element when inflating or deflating the inflatable element may be made or performed using a pressure gauge. The pressure gauge may be communicably coupled to the inflatable element.

[0028] The first or second structure may comprise a jacket, such as a jacket for supporting a wind turbine. The first or second structure may be a leg of a jacket. As such, the first structure may be substantially cylindrical.

[0029] The other of the first or second structure may comprise a foundation, such as a subsea pile. As such, the first structure may be substantially cylindrical.

[0030] For example, in use, the first structure may be disposed within the second structure, or vice versa. For example, an outer surface of the first structure may be arranged within, or be substantially enclosed by, an inner surface of the second structure. The first and or second structures may be arranged substantially concentrically with each other. The gap may be an annulus between the first and second structures.

[0031] The method may further comprise the step of disposing grout, such as concrete, within the gap after the first structure is stabilized and/or lifted and/or separated relative to the second structure. Such grout may prevent movement, e.g. further movement, of the first structure relative to the second structure.

[0032] The fluid may comprise sea-water. The fluid may be purified or filtered water. The fluid may be a liquid, such as hydraulic fluid, an oil, or the like.

[0033] In use, the gap may be disposed below a surface of the sea. In use, pressurisation and/or depressurisation of the inflatable element may be controlled from surface.

[0034] Advantageously, by controlling the pressurisation and/or depressurisation of the inflatable element from surface, costs and risks may be minimised by limiting the use of ROVs and/or divers during the installation process.

[0035] According to a second aspect of the present invention there is provided a method of stabilizing and/or lifting and/or separating a first structure relative to a second structure, the method comprising the steps of: determining a volume of fluid required to inflate each inflatable element of a plurality of inflatable elements disposed in a gap between the first and second structures to a first pressure level; based on the volume of fluid required and a characteristics of each inflatable element, determining a pressure level required for each inflatable element to provide a desired stabilizing and/or lifting and/or separating force to be applied to the structures by the inflatable element; and further inflating each inflatable element to the respective determined pressure level.

[0036] Advantageously, by inflating a plurality of inflatable elements in the gap, a stabilizing and/or lifting and/or separating force may be distributed across or around one or more surfaces of the first and/or second structure.

[0037] The step of determining a pressure level required for each inflatable element may comprise determining a size of the gap at the location of each inflatable element based on the volume of fluid required to fill each inflatable element and a first characteristic of each inflatable element

[0038] The step of determining a pressure level required for each inflatable element may comprise determining a pressure level required for each inflatable element to provide a desired stabilizing and/or lifting and/or separating force to be applied to the structures by the inflatable element based on the determined size of each gap and a second characteristic of each inflatable element.

[0039] The plurality of inflatable elements may comprise at least one pair of inflatable elements.

[0040] The method may further comprise a step, e.g. an initial step, of disposing at least one pair of inflatable elements in the gap between the first and second structures, such that the at least one pair of inflatable elements are disposed at substantially opposite, or opposing, sides of the structures.

[0041] Advantageously, by arranging the inflatable elements as pairs, and in particular by arranging the inflatable elements as substantially opposing or opposite pairs, substantially equal and opposite forces may be more readily applied to substantially opposite sides of the first and second structures, thus further stabilizing the first structure relative to the second structure.

[0042] The method may further comprise a step, e.g. an initial step, of circumferentially disposing, or substantially circumferentially disposing, a plurality of inflatable elements in an annular gap between the first and second structures.

[0043] The step of further inflating each inflatable element to the respective determined pressure level may comprise further inflating each inflatable element such that substantially equal and/or opposing stabilizing and/or lifting and/or separating forces are applied to the to the structures by the at least one pair of inflatable elements.

[0044] According to a third aspect of the present invention there is provided a method of stabilizing and/or lifting and/or separating a first structure relative to a second structure, the method comprising the steps of: disposing a plurality of inflatable elements in a gap between the first and second structures; based on a determined size of the gap and a characteristic of the inflatable element, determining a pressure level required in each inflatable element to apply equal substantially stabilizing and/or lifting and/or separating forces to the structures by the each of the inflatable elements; and inflating each inflatable element to the respective required pressure level.

[0045] The plurality of inflatable elements may be arranged as one or more substantially opposing pairs of inflatable elements, such that the stabilizing and/or lifting and/or separating forces from each inflatable element of a pair of inflatable elements are applied in substantially opposing directions. The plurality of inflatable elements may be evenly distributed in the gap. The gap may be an annulus between the first and second structures.

[0046] According to a fourth aspect of the present invention there is provided a method of stabilizing and/or lifting and/or separating a first structure relative to a second structure, the method comprising the steps of: determining a required pressure level to provide a desired stabilizing and/or lifting and/or separating force to be applied to the structures by the inflatable element; inflating the inflatable element to pressure level substantially greater than the required pressure level; and deflating the inflatable element to the required pressure level.

[0047] Advantageously, by effectively initially overinflating e.g. over pressurizing the inflatable element, a deformation of the inflatable element may be maximised, thus maximising a surface area of the inflatable element in contact with, and thus applying a force to, the first and/or second structure.

[0048] According to a fifth aspect of the present invention there is provided a system for stabilizing and/or lifting and/or separating a first structure relative to a second structure, the system comprising: at least one inflatable element for disposing between the first structure and the second structure; an arrangement or means for controlling and determining a fluid pressure in the at least one inflatable element; and an arrangement or means for measuring a volume of fluid used to inflate the at least one inflatable element.

[0049] The system may comprise the first structure. The system may comprise at least one pair of inflatable elements arranged at substantially opposite or opposing sides of the first structure.

[0050] A periphery of the at least one inflatable element may comprise at least one corner. The at least one corner may comprise a concave portion.

[0051] A periphery of the/each inflatable element or cushion may comprises at least one corner. The or each at least one corner may comprise a concave portion.

[0052] The/each inflatable element may comprise a plurality of corners. Each corner may comprise a concave portion;

[0053] A periphery of the/each inflatable elements may correspond to a substantially rectilinear shape. The substantially rectilinear shape may comprise concave cutaway portions at each corner.

[0054] The periphery of the/each inflatable element may comprise at least one pair of symmetrical sides. Each side of the periphery may comprise a substantially straight portion.

[0055] The at least one concave portion may be joined to an adjacent side of the periphery by at least one curved and/or radiused and/or convex portion.

[0056] A length or extent of the at least one concave portion may be greater than a length or extent of a/the curved, radiused and/or convex portion.

[0057] Each straight portion may be adjoined to an adjacent straight portion by at least one concave portion.

At least two curved and/or radiused and/or convex portions and/or each straight portion may be adjoined to an adjacent straight portion by, in sequence, a convex portion, a concave portion, and a convex portion.

[0058] The arrangement or means for controlling and determining a fluid pressure in the at least one inflatable element may be a flow meter. The flow meter may be communicably coupled to the inflatable element.

[0059] The arrangement or means for measuring a volume of fluid used to inflate the at least one inflatable element may be a pressure gauge. The pressure gauge may be communicably coupled to the inflatable element.

[0060] According to a sixth aspect of the present invention there is provided a method of testing the integrity of the system according to the fifth aspect, the method comprising the steps of: configuring the arrangement or means for controlling and determining a fluid pressure in the at least one inflatable element to decrease a pressure in the inflatable element to a pressure level below a default pressure, and subsequently assessing whether the pressure level below the default pressure is maintained after a period of time.

[0061] The default pressure may be atmospheric pressure. The default pressure may correspond to a depth below a surface of the sea of the inflatable element.

[0062] The pressure level below the default pressure may be provided using a pump, such as a vacuum pump.

[0063] According to a seventh aspect of the present invention there is provided a method for installing an inflatable element for stabilizing and/or lifting and/or separating a first structure relative to a second structure; the method comprising the steps of: providing the first structure with centralisers or supports for respectively centralising or supporting the first structure relative to the second structure; disposing the inflatable element in a deflated configuration between a pair of centralisers or supports, such that the inflatable element in the deflated configuration does not interfere with the second structure when the first structure is centralised or supported relative to the second structure by the centralisers or supports for respectively.

[0064] The step of disposing the inflatable element in a deflated configuration between a pair of centralisers or supports may comprise seating the inflatable element on at least one centraliser or support.

[0065] According to an eighth aspect of the present invention there is provided a first structure configured to support an inflatable element for stabilizing and/or lifting and/or separating the first structure relative to a second structure, the first structure comprising at least three supports and/or centralisers for supporting an inflatable element relative to the first structure.

[0066] The at least three supports and/or centralisers may be arranged in a substantially V-shaped configuration

[0067] The at least three supports and/or centralisers may be mounted on a surface of the first structure.

[0068] The first structure may be a jacket for supporting a wind turbine.

[0069] According to a ninth aspect of the present invention there is provided an apparatus for stabilizing and/or lifting and/or separating a first structure relative to a second structure, the apparatus comprising: a connection arrangement for connecting the apparatus to a support arrangement of a first structure; and a plurality of inflatable elements.

[0070] The connection arrangement may be adapted to be slidably and/or releasably engagable with the support arrangement on the first structure.

[0071] The connection arrangement may comprise a frame. The plurality of inflatable elements may be supported by the frame. Each inflatable element may be communicably coupled to a manifold and/or valve supported by the frame.

[0072] A periphery of the/each inflatable element or cushion may comprise at least one corner. The or each at least one corner may comprise a concave portion.

[0073] The/each inflatable element may comprise a plurality of corners. Each corner comprises a concave portion.

[0074] A periphery of the/each inflatable element may correspond to a substantially rectilinear shape. The substantially rectilinear shape may comprise concave cutaway portions at each corner.

[0075] The periphery of the/each inflatable element may comprise at least one pair of symmetrical sides. Each side of the periphery may comprise a substantially straight portion.

[0076] It will be appreciated that embodiments of the present invention relating to stabilizing and/or lifting and/or separating may be capable of positioning, locating, securing, jacking, packing, gripping, holding or centralising one item, e.g. member or structure, relative to another item, e.g. member or structure.

[0077] It will, therefore, be appreciated that herein "stabilizing" and/or "lifting" and/or "separating" is/are meant to include or comprise any of the aforementioned and at least in some embodiments the terms "stabilizer", "packer" and "gripper" or "gripping" may be used synonymously or similarly. Such terms also apply in respect of "stabilizing force" and/or "lifting force" and or "separating force".

[0078] It should be understood that the features defined above in accordance with any aspect of the present invention or below relating to any specific embodiment of the invention may be utilised, either alone or in combination with any other defined feature, in any other aspect or embodiment or to form a further aspect or embodiment of the invention.

BRIEF DESCRIPTION OF DRAWINGS

[0079] These and other aspects of the present invention will now be described, by way of example only, with reference to the accompanying drawings, which are:

Figure 1 a perspective view of an inflatable element as embodied in the methods and systems of the present invention;

Figure 2 a perspective view of a portion of a structure according to embodiments of the present invention with a plurality of inflatable elements installed;

Figure 3 a perspective view of a portion of a structure showing an arrangement of centralisers or supports for respectively centralising or supporting, according to an embodiment of the invention;

Figure 4 a perspective view of an example template for installing the centralisers or supports shown in Figure 3;

Figure 5 a further perspective view of a portion of another structure, and a cross-sectional view of one of the centralisers or supports;

Figure 6 a further perspective view of a portion of the structure of Figure 4 with an inflatable element installed, and also a further perspective view of the structure;

Figure 7 a perspective view of a portion of the structure shown in Figure 6, showing the installed inflatable elements;

Figure 8a a further perspective view of the portion of the structure of Figure 3, showing installed inflatable elements;

Figure 8b a top view of the portion of the structure of Figure 8a;

Figure 9a a further perspective view of the portion of the structure of Figure 5, showing installed inflatable elements;

Figure 9b a magnified view of one of the inflatable elements of Figure 9a;

Figure 10a a representation of an installed inflatable element in a retracted configuration;

Figure 10b a representation of the installed inflatable element of Figure 10a, in an inflated configuration;

Figure 11 a diagram showing a system for stabilizing and/or lifting and/or separating a first structure relative to a second structure according to an embodiment of the invention;

Figure 12 a magnified view of a portion of the diagram of Figure 11;

Figure 13 example data embodying a first characteristic of an inflatable device;

Figure 14 example data embodying a second characteristic of an inflatable device;

Figure 15 example data embodying a third characteristic of an inflatable device;

Figure 16a a schematic representation of a cross-sectional view of inflatable elements in use for stabilizing concentrically arranged first and second structures;

Figure 16b a schematic representation of a cross-sectional view of inflatable elements in use for stabilizing non-concentrically arranged first and second structures; and

Figure 17 a flow diagram of a method of stabilizing and/or lifting and/or separating a first structure relative to a second structure.

DETAILED DESCRIPTION OF DRAWINGS

[0080] Referring to Figures 1 to 10b, there is shown example embodiments of an inflatable element, and examples of methods and systems for installation of such an inflatable element, in accordance with embodiments of the present invention, as will be described below in more detail.

[0081] Referring to Figures 11 to 17b, there is shown example methods of use of the inflatable elements, in accordance with embodiments of the present invention, as will be described below in more detail.

[0082] Figure 1 shows an inflatable element, generally denoted 10, as described in UK Patent Application No. 1814224.0 (W3G Marine Ltd). In the example embodiment shown, the inflatable element 10 comprises four inflatable section 15a, 15b, 15c, 15d. It will be appreciated that in other embodiments falling within the scope of the present invention, the inflatable element 10 may comprise fewer than or greater than four inflatable sections.

[0083] The plurality of inflatable sections 15a, 15b, 15c, 15d are arranged in a stack, although for illustrative purposes they are shown in an exploded view in Figure 1.

[0084] Notably, a periphery of each inflatable section 15a, 15b, 15c, 15d comprises four corners, each corner comprising a concave portion 30a, 30b, 30c, 30d. That is, the periphery of each inflatable section 15a, 15b, 15c, 15d corresponds to a substantially rectangular/rectilinear shape with concave cut-away portions 30a, 30b, 30c, 30d at each corner.

[0085] In further embodiments of the inflatable element, also described in UK Patent Application No. 1814224.0 (W3G Marine Ltd), the inflatable sections are communicably coupled.

[0086] Figure 2 shows a perspective view of a portion of a structure 100 with a plurality of inflatable elements 110, 120 installed. The structure 100 is a jacket for supporting an offshore wind turbine. It will be appreciated that the jacket is for example purposes only, and the present invention is equally applicable to other structures, such as structures used in the on-shore building and construction industry.

[0087] The structure 100 comprises a plurality of centralisers or supports 130a-g arranged on an outer surface of the structure 100. Each inflatable element 110, 120 is disposed between a pair of centralisers or supports 130a, 130b; 130d, 130e. Furthermore, each inflatable element 110, 120 is seated on a centraliser or support 130f, 130g.That is, at least three of the centralisers or supports 130a, 130b, 130f are arranged in a substantially V-shaped configuration for supporting the inflatable element therebetween 110.

[0088] In the example embodiment shown, each inflatable section of an inflatable element 110, 120 is communicably connected to a hose 140, 150. Each hose 140, 150 may be an inflation line. As such, a plurality of inflatable sections of each inflatable element 110, 120 can be inflated or deflated collectively, i.e. together or in parallel. In other embodiments, also falling within the scope of the present invention, individual control of the inflation and/or deflation of inflatable sections of each inflatable element 110, 120 may be implemented, e.g. by individual hoses connecting each inflatable section of each inflatable element 110, 120. Furthermore, as described in UK Patent Application No. 1814224.0 (W3G Marine Ltd), the inflatable sections within an inflatable element may be communicably coupled such that a connection by the hose 140, 150 to a single inflatable section may inflate all of the inflatable sections of an inflatable element 110, 120.

[0089] Turning now to Figure 3, there is shown a perspective view of a portion of a structure 200, showing an arrangement of centralisers or supports 230a-g for centralising or supporting structure 200 relative to another structure (not shown). The structure 200 comprises a limiter 240 to limit an extent to which the structure 200 can be inserted into a further structure. In the example shown, the structure 200 is a portion of a leg of a jacket for supporting an off-shore wind turbine. The further structure (not shown) may be a cylindrical pile or foundation, against which the jacket leg is to be secured or stabilized. As such, the centralisers or supports 230a-g may be disposed in an annular gap between the structure 200 and the further structure, in use. The centralisers or supports 230a-g may serve to guide the structure 200 into the further structure. Furthermore, the centralisers or supports 230a-g may also protect any inflatable element disposed between the centralisers or supports 230a-g during installation of the structure 200 into the further structure. Each inflatable element will have at least three centralisers or supports providing protection.

[0090] Figure 4 shows a perspective view of an example template 300 for installing the centralisers or supports 230a-g shown in Figure 3. The template 300 comprises two substantially parallel bars 310, 320, connected by joining members, e.g. perpendicular struts in the example embodiment of Figure 4. Each bar 310, 320 comprises an arrangement or means for attaching a plurality of centralisers or supports 330a-e. Various means may be employed to attach centralisers or supports 330a-e to the template 300, such as bolting, clamping, screwing or the like. In use, the template 300 is used to hold a plurality of centralisers or supports 330a-e against a structure. The plurality of centralisers or supports 330a-e are then welded, or otherwise adhered or attached to the structure, and the template 300 subsequently removed, e.g. detached from each of the plurality of centralisers or supports 330a-e. As such, the plurality of centralisers or supports 300a-e can be fitted to a structure to define a first, upper row of centralisers or supports 330a, 330b and a second, lower row of centralisers or supports 330c, 330d, 330e. In this manner, the plurality of centralisers or supports 330a-e can be fitted and reliably spaced apart such that an inflatable element can be disposed between a pair of centralisers or supports 330a, 330b on the upper row of centralisers or supports, and/or also seated on a centraliser or support 330d in the lower row of centralisers or supports.

[0091] Figure 5 shows a further example of a structure 400 comprising an arrangement of centralisers or supports 430a-l for centralising or supporting the structure 400 relative to another structure (not shown). The structure 400 comprises a limiter 440 to limit an extent to which the structure 400 can be inserted into a further structure. In the example shown, the structure 400 is a portion of a leg of a jacket for supporting an off-shore wind turbine. As such, the further structure (not shown) may be a cylindrical pile or foundation, against which the jacket leg is to be secured or stabilized. In use, the centralisers or supports 430a-l may be disposed in an annular gap between the structure 400 and the further structure.

[0092] Also shown in Figure 5 is a cross-sectional view of one of the centralisers or supports 430a. Each centraliser or support 430a-l is substantially wedge shaped, e.g. tapered, such that a radial extent of the centralisers or supports increase towards an upper portion of the centralisers or supports, thus providing a sloping surface 450 relative to a surface of the structure 400. As such, the centralisers or supports may help guide the structure 400 into a further structure (not shown) is use. Furthermore, a thickness of an upper portion of each centraliser or support 430a-l is sufficiently greater than a thickness of an inflatable element 10, 110, 120 in a deflated or retracted configuration, such that the centralisers or supports 430a-l may protect the inflatable element 10, 110, 120 from interfering, e.g. contacting, the further structure during installation of the structure 400 within the further structure. Furthermore, the centralisers or supports 430a-l may ensure a minimum gap between the structures is provided for subsequent cementing or grouting operations.

[0093] Figure 6 shows a further perspective view of a portion of the structure 200 of Figure 3, with a plurality of inflatable elements installed 260a, 260b, 260c installed. Furthermore, the structure 200 is also shown, wherein the structure 200 is a jacket for supporting an off-shore wind turbine. In the example embodiment of Figure 6, inflatable elements 260a, 260b, 260c are shown disposed on one leg 250a of the structure 200. It will be appreciated that in other embodiments, the inflatable elements 110, 120 may be installed on any number of legs 250a, 250b, 250c or the structure. Furthermore, the structure 200 is provided for purposes of example only, and such inflatable elements 260a, 260b, 260c may be installed on other jackets or structures, such as jackets comprising four or more legs.

[0094] Figure 7 provides a magnified view of a portion of the structure 200 of Figures 3 and 6, the structure 200 comprising four inflatable elements - of which two inflatable elements 260a, 260b are visible. Each inflatable element 260a, 260b is communicably coupled to a corresponding hose 270a-d, such that each inflatable element 260a, 260b can be individually controlled, e.g. inflated (pressurised) or deflated (depressurised) remotely, e.g. from surface.

[0095] Figure 8a provides a magnified view of a portion of the structure 200 of Figures 3, 6 and 7, the structure 200 comprising four inflatable elements - of which three inflatable elements 260b, 260c, 260d are visible. Figure 8b shows a corresponding cross-sectional view of the structure 200 of Figure 8a, wherein all four inflatable elements 260a-d are visible. In the example embodiment of Figure 8a, the inflatable elements 260a-d are disposed in pairs, such that each pair of inflatable elements 260a, 260c; 260b, 260d comprises an inflatable element 260a, 260b arranged at a substantially opposite side of the structure 200 than the other inflatable element 260c, 260d of the pair.

[0096] Figure 9 shows a method of installing an inflatable element on the structure 400. The inflatable element 530 comprises a plurality of inflatable sections, and the inflatable sections are held together by means of a basket 510. The basket 510 may comprise metal. The basket 510 may comprise a substantially flexible material, such that in use the basket 510 may deform with the inflatable element 530 without substantially inhibiting inflation (pressurization) of the inflatable element 530.

[0097] The inflatable element 530 is supported by a frame 560.

[0098] Each inflatable section of the inflatable element 530 is communicably coupled to a manifold 540. The manifold 540 is also supported by the frame 560. The manifold 540 provides a coupling 550 to a further hose, e.g. hose 270a, such that, in use, the inflatable element, e.g. all inflatable sections of the inflatable element 530, can be inflated (pressurized) and/or deflated (depressurized) by means of the further hose.

[0099] Advantageously, by connecting all of the inflatable sections of the inflatable element 530 to a manifold 540 supported by the frame 560, a coupling between the hose and the manifold 540 may be inhibited from movement as the inflatable elements are inflated. Such inhibition of movement may prevent damage to the hose, the manifold, the inflatable elements and/or any coupling therebetween.

[0100] A pair of centralisers or supports 460a, 460b are fitted with a coupling portions or bosses 570a, 570b. In use, the frame 560 is disposed between the structure 400 and the coupling portions of bosses 570a, 570b. In such a disposition, the inflatable element 530 is also supported by a lower centraliser or support 430g. Furthermore, the inflatable element 530 is also protected by upper centralisers or supports 430a, 430b.

[0101] Figure 10a is a representation of an alternative embodiment of an inflatable element 630 installed on a structure 600 in a deflated (retracted) configuration. Figure 10b is a representation of the installed inflatable element 630 of Figure 10a, in an inflated (pressurised) configuration. In this alternative configuration, each inflatable section 640a, 640b, 640c, 640d is adhered to an adjacent inflatable section 640a, 640b, 640c, 640d. This provides an alternative to the basket 510 of Figure 9. Furthermore, an innermost inflatable section 640a of the inflatable element 630, e.g. the inflatable section 640a closest to the structure 600 in use, is adhered to a frame 650. The frame 650 is configured to be directly coupled to corresponding supports or centralizers 660a, 660b. In the example embodiment shown, the frame 650 is bolted to the corresponding supports or centralizers 660a, 660b. In other embodiments, the frame 650 may be adhered, glued, welded, fused or otherwise attached to the corresponding supports or centralizers 660a, 660b or to another portion of the structure 600.

[0102] In some embodiments, and as exemplified in Figure 10a, an outermost inflatable section 640d of the inflatable element 630 comprises a protective coating 670. The protective coating may be an insulating coating, e.g. formed from an electrically insulating material.

[0103] In some embodiments, an innermost inflatable section 640a of the inflatable element 630 comprises a protective coating (not shown). The protective coating may be an insulating coating, e.g. formed from an electrically insulating material.

[0104] Referring to Figures 11 to 17b, there is shown example methods of use of the inflatable elements, in accordance with embodiments of the present invention.

[0105] Figure 11 is a diagram showing a system, generally denoted 700, for stabilizing and/or lifting and/or separating a first structure relative to a second structure according to an embodiment of the invention. In the example embodiment of Figure 11, the system comprises a plurality of inflatable elements 730a, 730b, 760c, 730d for disposing between the first structure and the second structure. In the example embodiment, each inflatable element 730a, 730b, 760c, 730d comprises four inflatable sections. The first structure is a jacket 750 for an offshore wind turbine. Each inflatable element 730a, 730b, 760c, 730d is connected to a corresponding hose 770a, 770b, 770c, 770d. Each hose is connected - at surface - to an arrangement or means for controlling and determining a fluid pressure in the inflatable elements, and an arrangement or means for measuring a volume of fluid used to inflate the inflatable elements, as will be described in more detail with reference to Figure 12.

[0106] Figure 12 shows a magnified view of a portion of the diagram of Figure 11. In particular, Figure 12 shows a portion of the system 700 that is located at surface. Operation of the system is now described with reference to Figures 13, 14 and 15, which provide example data embodying characteristics of the inflatable elements 730a, 730b, 730c, 730d.

[0107] In the example embodiment of Figures 11 and 12, valves V1, V2, V3, V4, P-A and P-B are disposed on the jacket 750, e.g. topside on the jacket 750. Further components of the system 700 are disposed in a container 780 disposed on a support vessel 790. That is, the arrangement or means for controlling and determining a fluid pressure in the inflatable elements 730a, 730b, 730c, 730d, and the arrangement or means for measuring a volume of fluid used to inflate the inflatable elements 730a, 730b, 730c, 730d, are disposed in the container 780.

[0108] It will be appreciated that in alternative embodiments of the present invention, the container 780, or components of the system 700 disposed within the container 780, may be disposed elsewhere on the support vessel 790, i.e. not in the container 780, and/or on the jacket 750, e.g. topside the jacket. In the example embodiment of Figures 11 and 12, valves C-A, C-B, C-C, C-D, C-E, C-F, C-Y and CZ are disposed in the container 780 on the support vessel 790. A hose 720 provides a connection between the container 780 and the jacket 750.

[0109] In an example embodiment, an initial configuration of each valve, e.g. a configuration of each valve when the operation of stabilizing the jacket 750 relative to a second structure such as a foundation pile, is closed. That is, all of valves V1, V2, V3, V4, P-A, P-B, C-A, C-B, C-C, C-D, C-E, C-F, C-Y and CZ are initially closed, thus inhibiting a flow of fluid.

[0110] During installation, as an initial configuration, a pressure in the inflatable elements 730a, 730b, 730c, 730d, may be set to a pressure level below a default pressure, e.g. below atmospheric pressure, or an otherwise naturally occurring pressure at a depth of installation of the inflatable elements. That is, fluid in the inflatable elements 730a, 730b, 730c, 730d may be pumped from the inflatable elements 730a, 730b, 730c, 730d to reduce the pressure for purposes of testing the integrity of the system. As such, a pressure at valves V1 - V4 may be a relatively low pressure as an initial condition.

[0111] The integrity of the system 700, and in particular the inflatable elements 730a, 730b, 730c, 730d is tested by installing a vacuum gauge (not shown) outboard of valve P-B, and subsequently opening valve P-B. Then, each of valves V-1 to V-4 will be opened and closed in turn, and the pressure on the vacuum gauge recorded. If the pressure on the vacuum gauge is within a predefined range, or below a predefined threshold, e.g. the measured pressure substantially corresponds to the previously defined pressure level below a default pressure, then the inflatable elements 730a, 730b, 730c, 730d are maintaining a pressure level, and thus are of adequate integrity e.g. are adequately fluid tight.

[0112] The next step in the process is to ensure that the hose 720 which provides a connection between the container 780 and the jacket 750 is filled. To do so, valves C-A, C-F and P-A are opened. An air operated fill pump is started to flush water through the hose until water is discharged from the hose, e.g. over the side of the platform, thus ensuring the hose contains no entrained air. The valve P-B on the platform is then closed.

[0113] The first stage of inflating/pressurising the inflatable elements 730a, 730b, 730c, 730d is to pressurise each inflatable element 730a, 730b, 730c, 730d separately to a predefined pressure level. In an example embodiment, the defined pressure level is 1 MPa. The predefined pressure level is selected based on determined characteristics of the inflatable elements 730a, 730b, 730c, 730d. That is, at the predefined pressure level, e.g. 1MPa, the inflatable elements 730a, 730b, 730c, 730d will have adequately expanded to fill a gap between a surface of the jacket 750 and the structure relative to which the jacket 750 is to be stabilized.

[0114] In order to inflate/pressurise each inflatable element 730a, 730b, 730c, 730d, the following sequence is carried out.

[0115] First, the air operated pump with the pressure regulator set to 1MPa, by operating valve C-Z. Then, valve P-B is opened to observe an adequate flow of fluid from the jacket topsides manifold to which valve P-B is communicably coupled.

[0116] Following this, valve P-B is temporarily closed, and a pressure gauge 765 is fitted, directly or indirectly via a jacket topside manifold, to valve P-B or to an output of valve P-B. Valve P-B is subsequently reopened. Thus, a pressure at valve P-B can be read from the pressure gauge 765.

[0117] Before commencing pressurisation/inflation of a first inflatable element 730a, a flow meter is calibrated by resetting the flow meter, e.g. setting a measurement of accumulated fluid flow to zero. Then, valve V1 is opened. Preferably, Valves V1, V2, V3 and V4 are needle valves. Preferably valve V-1 is opened slowly.

[0118] For purposes of illustration, the flow meter 775 is shown topside the jacket, and in a fluid path to each of the inflatable elements. It will be appreciated that, in other embodiments of the invention, the flow meter 775 may be disposed at other, different locations within the system. For example, the flow meter may be coupled to the hose 720, or disposed on the support vessel, such as within the container 780.

[0119] Fluid is then pumped into the first inflatable element 730a via valve V-1. When the defined pressure level, e.g. 1MPa, is established in the first inflatable element 730a, valve V-1 is closed. A volume of fluid required to establish the defined pressure level is recorded as a first measurement.

[0120] Before commencing pressurisation/inflation of a second inflatable element 730b, the flow meter is recalibrated by again resetting the flow meter, e.g. setting the measure of accumulated fluid flow to zero. Then, valve V-2 is opened. Preferably valve V-2 is opened slowly.

[0121] Fluid is then pumped into the second inflatable element 730b via valve V-2. When the defined pressure level, e.g. 1MPa, is established in the second inflatable element 730b, valve V-2 is closed. A volume of fluid required to establish the defined pressure level is recorded as a second measurement.

[0122] Before commencing pressurisation/inflation of a third inflatable element 730c, the flow meter is recalibrated by again resetting the flow meter, e.g. setting the measure of accumulated fluid flow to zero. Then, valve V-3 is opened. Preferably valve V-3 is opened slowly.

[0123] Fluid is then pumped into the third inflatable element 730c via valve V-3. When the defined pressure level, e.g. 1MPa, is established in the third inflatable element 730c, valve V-3 is closed. A volume of fluid required to establish the defined pressure level is recorded as a third measurement.

[0124] Before commencing pressurisation/inflation of a fourth inflatable element 730d, the flow meter is recalibrated by again resetting the flow meter, e.g. setting the measure of accumulated fluid flow to zero. Then, valve V-4 is opened. Preferably valve V-4 is opened slowly.

[0125] Fluid is then pumped into the fourth inflatable element 730d via valve V-2. When the defined pressure level, e.g. 1MPa, is established in the fourth inflatable element 730d, valve V-4 is closed. A volume of fluid required to establish the defined pressure level is recorded as a fourth measurement.

[0126] Example first characteristics of an inflatable element are show in Figure 13. The first characteristic is a relationship between a size of the gap and a volume of fluid required to inflate the inflatable element to the defined pressure level.

[0127] Figure 13 shows a volume of fluid required to inflate an inflatable element to a pressure of 1 MPa for a range of sizes of gap. In this example, the 'gap' refers to a space between the first and second structures, e.g. the jacket and the structure to which the jacket is stabilized. The inflatable element is disposed and inflated in the gap.

[0128] That is, based on the first characteristic as exemplified in Figure 13, a size of the gap into which an inflatable element is inflated to a defined pressure level can be derived from a volume of fluid required to inflate the inflatable element.

[0129] For example, based on the example characteristics of Figure 13, a fill volume of 50 Litres corresponds to a gap of 0.3 metres.

[0130] The first characteristic may be determined by means of simulation and/or testing of the inflatable element, or an equivalent or similar inflatable element. Such testing and/or simulation may typically take place onshore.

[0131] Thus, based on the first measurement, a size of the gap into which the first inflatable element 730a is disposed can be determined. Similar determinations can be made for the second, third and fourth inflatable elements 730b, 730c, 730d.

[0132] A next step is to further pressurise each inflatable element 730a, 730b, 730c, 730d to provide a stabilizing force to be jacket. In one embodiment of the invention, each inflatable element 730a, 730b, 730c, 730d is pressurized to a defined second pressure level to provide a desired loading to the structures to be stabilized. The defined second pressure level is determined based on the determined size of the gap and further characteristics of each inflatable element 730a, 730b, 730c, 730d.

[0133] In a further embodiment, each inflatable element 730a, 730b, 730c, 730d is initially inflated/pressurised to a third pressure level, the third pressure level being substantially greater than the second pressure level; and subsequently deflated to the second pressure level. In this manner, maximum deformation of a surface of the inflatable element can be achieved, thus increasing a load-distributing surface area of the inflatable element.

[0134] Example second characteristics of an inflatable element are show in Figure 14. The second characteristic is a relationship between a size of the gap and a pressure required in the inflatable element to provide a stabilizing force of 830kN. That is, continuing with the previous example and based on the characteristics of the inflatable element shown in Figure 13, in a gap determined to be 0.3m a pressure in each inflatable element would have to be increased to approximately 7MPa for the inflatable element to provide a stabilizing force of 830kN.

[0135] It will be appreciated that all pressures, volumes, forces and dimensions described herein are for purposes of example only, and that the invention is equally applicable to other dimensions, pressures, forces and volumes, which may depend upon at least one of: characteristic, dimensions, shapes and/or materials of the inflatable elements; characteristics of the fluid used.

[0136] The procedure, based on the example system of Figures 11 and 12 and the example stabilizing force of 830kN described above, is as follows.

[0137] The pressure regulator (C-Z) is set to the required pressure to establish 830kN force. Then, the air operated pump is started, with the with the pressure regulator (C-Z) set to establish an 830kN force. Then, valve V1 is opened - preferably slowly - to allow fluid to be pumped into the first inflatable element 730a until an 830kN force is provided by the inflatable element. A volume of fluid required to achieve the 830kN force is measured, and logged. Advantageously, a volume of fluid outside predetermined threshold, e.g. an excessively high or low volume of fluid, may be used as an indication of a fault in the system. Valve V-1 is then closed.

[0138] The procedure is repeated for each of the second inflatable element 730b using valve V-2, the third inflatable element 730c using valve V-3, and the fourth inflatable element 730d using valve V-4.

[0139] Example third characteristics of an inflatable element are show in Figure 15. The third characteristic is a relationship between a size of the gap and a pressure required in the inflatable element to reduce the stabilizing force of 830kN to 450kN. That is, continuing with the previous example and based on the characteristics of the inflatable element shown in Figure 14, in a gap determined to be 0.3m a pressure in each inflatable element would have to be decreased from 7MPa to 4MPa for the inflatable element to provide a stabilizing force of 450kN.

[0140] The process for reducing the pressure is as follows.

[0141] Valve P-A is opened. Then, each of valves V-1, V-2, V-3 and V-4 are individually opened, preferably slowly, to relieve the pressure to the 4MPa, and then closed again to sustain the pressure at 4MPa.

[0142] An optional further step may remove equipment from the jacket topside. The optionally further step may comprise closing valves P-A and P-B, removing the pressure gauge, and disconnecting hose 720.

[0143] Figure 16a shows a schematic representation of a cross-sectional view of a schematic representation of inflatable elements in use for stabilizing a concentrically arranged first structure 800 relative to a second structure 810. Four inflatable elements 830a, 830b, 830c, 830d provide a stabilizing force between the first structure 800 relative to a second structure 810. Due to the concentric arrangement of the first and second structures, a pressure required in each of the four inflatable elements 830a, 830b, 830c, 830d is substantially the same.

[0144] Figure 16b is a schematic representation of an alternative arrangement, wherein inflatable elements 830a, 830b, 830c, 830d are provided for stabilizing a non-concentrically arranged first structure 800 relative to a second structure 810. In this case, a larger fluid pressure is required in first inflatable element 830a compared to third inflatable element 830c to provide equal and opposite forces acting on the structures 800, 810. For example, if the first inflatable element 830a fills a gap of 0.4m, and by adhering to the example data provided in Figure 15, a fluid pressure of approximately 5MPa is required to provide a stabilizing force of 450kN. In contrast, if the third inflatable element 830c fills a gap of 0.12m, and by adhering to the example data provided in Figure 15, a fluid pressure of approximately 3.1MPa is required to provide a stabilizing force of 450kN.

[0145] Figure 17 shows a flow diagram of a method of stabilizing and/or lifting and/or separating a first structure relative to a second structure. In a first step 910 of determining a volume of fluid required to inflate an inflatable element disposed in a gap between a first and a second structure to a first pressure level.

[0146] The method comprises a second step 920. In the second step 920, based on the volume of fluid required and characteristics of the inflatable element, a second pressure level required to provide a desired stabilizing and/or lifting and/or separating force to be applied to the structures by the inflatable element is determined.

[0147] The method comprises a third step 930. In the third step 930, the inflatable element is further inflated to the second pressure level.

[0148] It will be appreciated that the embodiments of the present invention hereinbefore described are given by way of example only and are not meant to limit the scope of thereof in any way. It will be appreciated that embodiments of the present invention provide benefits over the prior art.

[0149] It will also be appreciated that embodiments of the present invention may provide a beneficial or advantageously (low) input force (pressure) to inflatable element expansion ratio or "stroke". It will further be appreciated that while the disclosed embodiments show rectilinear inflatable members, other shapes (closed shapes) of inflatable members may be envisaged, e.g. having three or more corners, wherein at least one of the corners comprises a concave portion.

NUMBERED CLAUSES

[0150]

Clause 1. A method of stabilizing and/or lifting and/or separating a first structure relative to a second structure, the method comprising the steps of:

determining a volume of fluid required to inflate an inflatable element disposed in a gap between the first and second structures to a first pressure level;
based on the volume of fluid required and characteristics of the inflatable element, determining a second pressure level required to provide a desired stabilizing and/or lifting and/or separating force to be applied to the structures by the inflatable element; and
further inflating the inflatable element to the second pressure level.

Clause 2. The method of clause 1, wherein the step of determining a second pressure level comprises:

determining a size of the gap based on the volume of fluid required and a first characteristic of the inflatable element; and
making a determination of the second pressure level based on the determined size of the gap and a second characteristic of the inflatable element.

Clause 3. The method of clauses 1 or 2, wherein the step of further inflating the inflatable element to the second pressure level comprises the steps of:

initially inflating the inflatable element to a third pressure level, the third pressure level being substantially greater than the second pressure level; and
subsequently deflating the inflatable element to the second pressure level.

Clause 4. The method of clause 3, wherein the determination of the third pressure level is based on the determined size of the gap and a third characteristic of the inflatable element.

Clause 5. The method of clauses 2, 3 or 4, wherein the first characteristic is a relationship between the size of the gap and a volume of fluid required to inflate the inflatable element to the first pressure level.

Clause 6. The method of any of clauses 2 to 5, wherein the second and/or third characteristics are relationship between the size of the gap and pressure level required to provide the desired stabilizing force.

Clause 7. The method of any of clauses 2 to 6, further comprising the steps of characterising the inflatable element, or an equivalent inflatable element, by means of simulation and/or testing to determine the first and/or second and/or third characteristics.

Clause 8. The method of any preceding clause, comprising the step of disposing the at least one inflatable element in the gap between the first and second structures.

Clause 9. The method of any preceding clause, further comprising the step of testing the integrity of the inflatable element by decreasing the pressure in the inflatable element to a pressure level below a default pressure, and subsequently assessing whether the pressure level below the default pressure is sustained after a period of time.

Clause 10. The method of any preceding clause, wherein:

the determination of the volume of fluid required to inflate the inflatable element is made using a flow meter, the flow meter being communicably coupled to the inflatable element; and/or
a determination of a pressure level in the inflatable element when inflating or deflating the inflatable element is made using a pressure gauge, the pressure gauge being communicably coupled to the inflatable element.

Clause 11. The method of any preceding clause, wherein the first structure comprises a jacket, such as a jacket for supporting a wind turbine, and the second structure comprises a foundation, such as a subsea pile.

Clause 12. The method of any preceding clause, further comprising the step of disposing grout, such as concrete, within the gap after the first structure is stabilized and/or lifted and/or separated relative to the second structure.

Clause 13. The method of any preceding clause, wherein the fluid comprises sea-water.

Clause 14. The method of any preceding clause wherein, in use, the gap is disposed below a surface of the sea, and pressurisation and/or depressurisation of the inflatable element is controlled from surface.

Clause 15. A method of stabilizing and/or lifting and/or separating a first structure relative to a second structure, the method comprising the steps of:

determining a volume of fluid required to inflate each inflatable element of a plurality of inflatable elements disposed in a gap between the first and second structures to a first pressure level;
based on the volume of fluid required and a characteristic(s) of each inflatable element, determining a pressure level required for each inflatable element to provide a desired stabilizing and/or lifting and/or separating force to be applied to the structures by the inflatable element; and
further inflating each inflatable element to the respective determined pressure level.

Clause 16. The method of clause 15, wherein the step of determining a pressure level required for each inflatable element comprises:

determining a size of the gap at the location of each inflatable element based on the volume of fluid required to fill each inflatable element and a first characteristic of each inflatable element; and
based on the determined size of each gap and a second characteristic of each inflatable element, determining a pressure level required for each inflatable element to provide a desired stabilizing and/or lifting and/or separating force to be applied to the structures by the inflatable element.

Clause 17. The method of clauses 15 or 16, wherein the plurality of inflatable elements comprises at least one pair of inflatable elements, the method further comprising the initial step of:
disposing at least one pair of inflatable elements in the gap between the first and second structures, such that the at least one pair of inflatable elements are disposed at substantially opposite or opposing sides of the structures.

Clause 18. The method claim 17, wherein the step of further inflating each inflatable element to the respective determined pressure level comprises further inflating each inflatable element such that substantially equal and opposing stabilizing and/or lifting and/or separating forces are applied to the to the structures by the at least one pair of inflatable elements.

Clause 19. A method of stabilizing and/or lifting and/or separating a first structure relative to a second structure, the method comprising the steps of:

disposing a plurality of inflatable elements in a gap between the first and second structures;
based on a determined size of the gap and a characteristic of the inflatable element, determining a pressure level required in each inflatable element to apply equal stabilizing and/or lifting and/or separating forces to the structures by the each of the inflatable elements; and
inflating each inflatable element to the respective required pressure level.

Clause 20. The method of clause 19, wherein the plurality of inflatable elements are arranged as one or more substantially opposing pairs of inflatable elements, such that the stabilizing and/or lifting and/or separating forces from each inflatable element of a pair of inflatable elements are applied in substantially opposing directions.

Clause 21. A method of stabilizing and/or lifting and/or separating a first structure relative to a second structure, the method comprising the steps of:

determining a required pressure level to provide a desired stabilizing and/or lifting and/or separating force to be applied to the structures by the inflatable element;
inflating the inflatable element to pressure level substantially greater than the required pressure level; and
deflating the inflatable element to the required pressure level.

Clause 22. A system for stabilizing and/or lifting and/or separating a first structure relative to a second structure, the system comprising:

at least one inflatable element for disposing between the first structure and the second structure;
an arrangement or means for controlling and determining a fluid pressure in the at least one inflatable element; and
an arrangement or means for measuring a volume of fluid used to inflate the at least one inflatable element.

Clause 23. The system of clause 22, comprising the first structure and at least one pair of inflatable elements arranged at substantially opposite or opposing sides of the first structure.

Clause 24. The system of clause 22 or 23, wherein at least one of:

a periphery of the/each inflatable element or cushion comprises at least one corner, the or each at least one corner comprising a concave portion;
the/each inflatable element comprises a plurality of corners and each corner comprises a concave portion;
a periphery of the/each inflatable element corresponds to a substantially rectilinear shape with concave cut-away portions at each corner; and/or
wherein the periphery of the/each inflatable element comprises at least one pair of symmetrical sides and/or each side of the periphery comprises a substantially straight portion.

Clause 25. The apparatus of clause 24, wherein at least one of:

the at least one concave portion is joined to an adjacent side of the periphery by at least one curved, radiused and/or convex portion;
a length or extent of the at least one concave portion is greater than a length or extent of a/the curved, radiused and/or convex portion; and/or
each straight portion is adjoined to an adjacent straight portion by at least one concave portion and at least two curved, radiused or convex portions and/or each straight portion is adjoined to an adjacent straight portion by, in sequence, a convex portion, a concave portion, and a convex portion.

Clause 26. The system of any of clauses 22 to 25, wherein:

the arrangement or means for controlling and determining a fluid pressure in the at least one inflatable element is a flow meter, the flow meter being communicably coupled to the inflatable element; and/or
the arrangement or means for measuring a volume of fluid used to inflate the at least one inflatable element is a pressure gauge communicably coupled to the inflatable element.

Clause 27. A method of testing the integrity of the system of clause 22, the method comprising the steps of:
configuring the arrangement or means for controlling and determining a fluid pressure in the at least one inflatable element to decrease a pressure in the inflatable element to a pressure level below a default pressure, and subsequently assessing whether the pressure level below the default pressure is maintained after a period of time.

Clause 28. A method for installing an inflatable element for stabilizing and/or lifting and/or separating a first structure relative to a second structure; the method comprising the steps of:

providing the first structure with centralisers or supports for respectively centralising or supporting the first structure relative to the second structure;
disposing the inflatable element in a deflated configuration between a pair of centralisers or supports, such that the inflatable element in the deflated configuration does not interfere with the second structure when the first structure is centralised or supported relative to the second structure by the centralisers or supports for respectively.

Clause 29. The method of clause 28, wherein the step of disposing the inflatable element in a deflated configuration between a pair of centralisers or supports comprises seating the inflatable element on at least one centraliser or support.

Clause 30. A first structure configured to support an inflatable element for stabilizing and/or lifting and/or separating the first structure relative to a second structure, the first structure comprising at least three supports and/or centralisers for supporting an inflatable element relative to the first structure.

Clause 31. The first structure according to clause 30, wherein the at least three supports and/or centralisers are arranged in a substantially V-shaped configuration, and optionally wherein the at least three supports and/or centralisers are mounted on a surface of the first structure.

Clause 32. The structure of clauses 30 or 31, wherein the first structure is a jacket for supporting a wind turbine.

Clause 33. An apparatus for stabilizing and/or lifting and/or separating a first structure relative to a second structure, the apparatus comprising:

a connection arrangement for connecting the apparatus to a support arrangement of a first structure; and
a plurality of inflatable elements.

Clause 34. The apparatus of clause 33, wherein the connection arrangement is adapted to be slidably and/or releasably engagable with the support arrangement on the first structure.

Clause 35. The apparatus of either of clauses 33 or 34, wherein the connection arrangement comprises a frame, the plurality of inflatable elements being supported by the frame and/or each inflatable element being communicably coupled to a manifold and/or valve supported by the frame.

Clause 36. The apparatus of any of clauses 33 to 35, wherein at least one of:

a periphery of the/each inflatable element or cushion comprises at least one corner, the or each at least one corner comprising a concave portion; and/or
the/each inflatable element comprises a plurality of corners and each corner comprises a concave portion; and/or
a periphery of the/each inflatable element corresponds to a substantially rectilinear shape with concave cut-away portions at each corner; and/or
wherein the periphery of the/each inflatable element comprises at least one pair of symmetrical sides and/or each side of the periphery comprises a substantially straight portion.

Claims

1. A method of stabilizing and/or lifting and/or separating a first structure relative to a second structure, the method comprising the steps of:

determining a volume of fluid required to inflate an inflatable element disposed in a gap between the first and second structures to a first pressure level;
based on the volume of fluid required and characteristics of the inflatable element, determining a second pressure level required to provide a desired stabilizing and/or lifting and/or separating force to be applied to the structures by the inflatable element; and
further inflating the inflatable element to the second pressure level.

2. The method of claim 1, wherein the step of determining a second pressure level comprises:

determining a size of the gap based on the volume of fluid required and a first characteristic of the inflatable element; and
making a determination of the second pressure level based on the determined size of the gap and a second characteristic of the inflatable element.

3. The method of either of claims 1 or 2, wherein the step of further inflating the inflatable element to the second pressure level comprises the steps of:

initially inflating the inflatable element to a third pressure level, the third pressure
level being substantially greater than the second pressure level; and
subsequently deflating the inflatable element to the second pressure level, and in such case optionally
wherein the determination of the third pressure level is based on the determined size of the gap and a third characteristic of the inflatable element; and/or.

4. The method of any of claims 2, 3 or 4, wherein:

the first characteristic is a relationship between the size of the gap and a volume of fluid required to inflate the inflatable element to the first pressure level; and/or
the second and/or third characteristics are relationship between the size of the gap and pressure level required to provide the desired stabilizing force; and/or
the method further comprises the steps of characterising the inflatable element, or an equivalent inflatable element, by means of simulation and/or testing to determine the first and/or second and/or third characteristics.

5. The method of any preceding claim:

comprising the step of disposing the at least one inflatable element in the gap between the first and second structures; and/or
comprising the step of testing the integrity of the inflatable element by decreasing the pressure in the inflatable element to a pressure level below a default pressure, and subsequently assessing whether the pressure level below the default pressure is sustained after a period of time; and/or
wherein:

the determination of the volume of fluid required to inflate the inflatable element is made using a flow meter, the flow meter being communicably coupled to the inflatable element; and/or
a determination of a pressure level in the inflatable element when inflating or deflating the inflatable element is made using a pressure gauge, the pressure gauge being communicably coupled to the inflatable element; and/or

wherein the first structure comprises a jacket, such as a jacket for supporting a wind turbine, and the second structure comprises a foundation, such as a subsea pile; and/or
comprising the step of disposing grout, such as concrete, within the gap after the first structure is stabilized and/or lifted and/or separated relative to the second structure; and/or
wherein the fluid comprises sea-water; and/or
wherein, in use, the gap is disposed below a surface of the sea, and pressurisation and/or depressurisation of the inflatable element is controlled from surface.

6. A method of stabilizing and/or lifting and/or separating a first structure relative to a second structure, the method comprising the steps of:

determining a volume of fluid required to inflate each inflatable element of a plurality of inflatable elements disposed in a gap between the first and second structures to a first pressure level;
based on the volume of fluid required and a characteristic(s) of each inflatable element, determining a pressure level required for each inflatable element to provide a desired stabilizing and/or lifting and/or separating force to be applied to the structures by the inflatable element; and
further inflating each inflatable element to the respective determined pressure level.

7. The method of claim 6, wherein:

the step of determining a pressure level required for each inflatable element comprises:

determining a size of the gap at the location of each inflatable element based on the volume of fluid required to fill each inflatable element and a first characteristic of each inflatable element; and
based on the determined size of each gap and a second characteristic of each inflatable element, determining a pressure level required for each inflatable element to provide a desired stabilizing and/or lifting and/or separating force to be applied to the structures by the inflatable element; and/or

the plurality of inflatable elements comprises at least one pair of inflatable elements, the method further comprising the initial step of:

disposing at least one pair of inflatable elements in the gap between the first and second structures, such that the at least one pair of inflatable elements are disposed at substantially opposite or opposing sides of the structures, and optionally in such case the step of further inflating each inflatable element to the respective determined pressure level comprises further inflating each inflatable element such that substantially equal and opposing stabilizing and/or lifting and/or separating forces are applied to the to the structures by the at least one pair of inflatable elements.

8. A method of stabilizing and/or lifting and/or separating a first structure relative to a second structure, the method comprising the steps of:

disposing a plurality of inflatable elements in a gap between the first and second structures;
based on a determined size of the gap and a characteristic of the inflatable element, determining a pressure level required in each inflatable element to apply equal stabilizing and/or lifting and/or separating forces to the structures by the each of the inflatable elements; and
inflating each inflatable element to the respective required pressure level.

9. The method of claim 8, wherein the plurality of inflatable elements are arranged as one or more substantially opposing pairs of inflatable elements, such that the stabilizing and/or lifting and/or separating forces from each inflatable element of a pair of inflatable elements are applied in substantially opposing directions.

10. A method of stabilizing and/or lifting and/or separating a first structure relative to a second structure, the method comprising the steps of:

determining a required pressure level to provide a desired stabilizing and/or lifting and/or separating force to be applied to the structures by the inflatable element;
inflating the inflatable element to pressure level substantially greater than the required pressure level; and
deflating the inflatable element to the required pressure level.

11. A system for stabilizing and/or lifting and/or separating a first structure relative to a second structure, the system comprising:

at least one inflatable element for disposing between the first structure and the second structure;
an arrangement or means for controlling and determining a fluid pressure in the at least one inflatable element; and
an arrangement or means for measuring a volume of fluid used to inflate the at least one inflatable element.

12. The system of claim 11:

comprising the first structure and at least one pair of inflatable elements arranged at substantially opposite or opposing sides of the first structure; and/or
wherein at least one of:

a periphery of the/each inflatable element or cushion comprises at least one corner, the or each at least one corner comprising a concave portion;
the/each inflatable element comprises a plurality of corners and each corner comprises a concave portion;
a periphery of the/each inflatable element corresponds to a substantially rectilinear shape with concave cut-away portions at each corner; and/or
wherein the periphery of the/each inflatable element comprises at least one pair of symmetrical sides and/or each side of the periphery comprises a substantially straight portion, and in such case optionally

wherein at least one of:

the at least one concave portion is joined to an adjacent side of the periphery by at least one curved, radiused and/or convex portion;
a length or extent of the at least one concave portion is greater than a length or extent of a/the curved, radiused and/or convex portion; and/or
each straight portion is adjoined to an adjacent straight portion by at least one concave portion and at least two curved, radiused or convex portions and/or each straight portion is adjoined to an adjacent straight portion by, in sequence, a convex portion, a concave portion, and a convex portion; and in any case

wherein:

the arrangement or means for controlling and determining a fluid pressure in the at least one inflatable element is a flow meter, the flow meter being communicably coupled to the inflatable element; and/or
the arrangement or means for measuring a volume of fluid used to inflate the at least one inflatable element is a pressure gauge communicably coupled to the inflatable element.

13. A method of testing the integrity of the system of claim 11, the method comprising the steps of: configuring the arrangement or means for controlling and determining a fluid pressure in the at least one inflatable element to decrease a pressure in the inflatable element to a pressure level below a default pressure, and subsequently assessing whether the pressure level below the default pressure is maintained after a period of time.

14. A method for installing an inflatable element for stabilizing and/or lifting and/or separating a first structure relative to a second structure; the method comprising the steps of:

providing the first structure with centralisers or supports for respectively centralising or supporting the first structure relative to the second structure;
disposing the inflatable element in a deflated configuration between a pair of centralisers or supports, such that the inflatable element in the deflated configuration does not interfere with the second structure when the first structure is centralised or supported relative to the second structure by the centralisers or supports for respectively.

15. The method of claim 14, wherein the step of disposing the inflatable element in a deflated configuration between a pair of centralisers or supports comprises seating the inflatable element on at least one centraliser or support.

16. A first structure configured to support an inflatable element for stabilizing and/or lifting and/or separating the first structure relative to a second structure, the first structure comprising at least three supports and/or centralisers for supporting an inflatable element relative to the first structure.

17. The first structure according to claim 16, wherein:

the at least three supports and/or centralisers are arranged in a substantially V-shaped configuration, and optionally wherein the at least three supports and/or centralisers are mounted on a surface of the first structure; and/or
the first structure is a jacket for supporting a wind turbine.

18. An apparatus for stabilizing and/or lifting and/or separating a first structure relative to a second structure, the apparatus comprising:

a connection arrangement for connecting the apparatus to a support arrangement of a first structure; and
a plurality of inflatable elements.

19. The apparatus of claim 18, wherein:

the connection arrangement is adapted to be slidably and/or releasably engagable with the support arrangement on the first structure; and/or
the connection arrangement comprises a frame, the plurality of inflatable elements being supported by the frame and/or each inflatable element being communicably coupled to a manifold and/or valve supported by the frame; and/or
wherein at least one of:

a periphery of the/each inflatable element or cushion comprises at least one corner, the or each at least one corner comprising a concave portion; and/or
the/each inflatable element comprises a plurality of corners and each corner comprises a concave portion; and/or
a periphery of the/each inflatable element corresponds to a substantially rectilinear shape with concave cut-away portions at each corner; and/or

wherein the periphery of the/each inflatable element comprises at least one pair of symmetrical sides and/or each side of the periphery comprises a substantially straight portion.

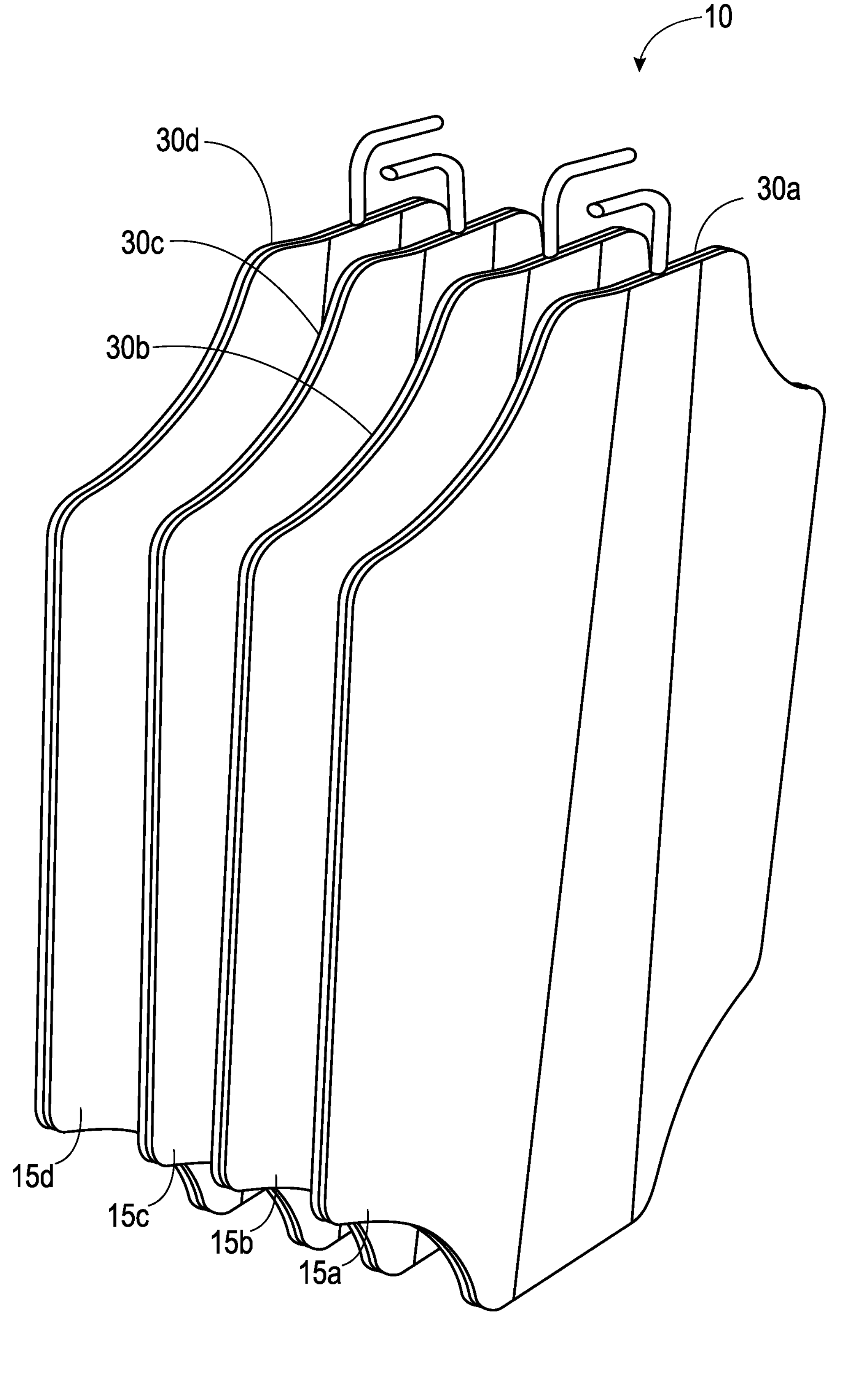

FIG. 1

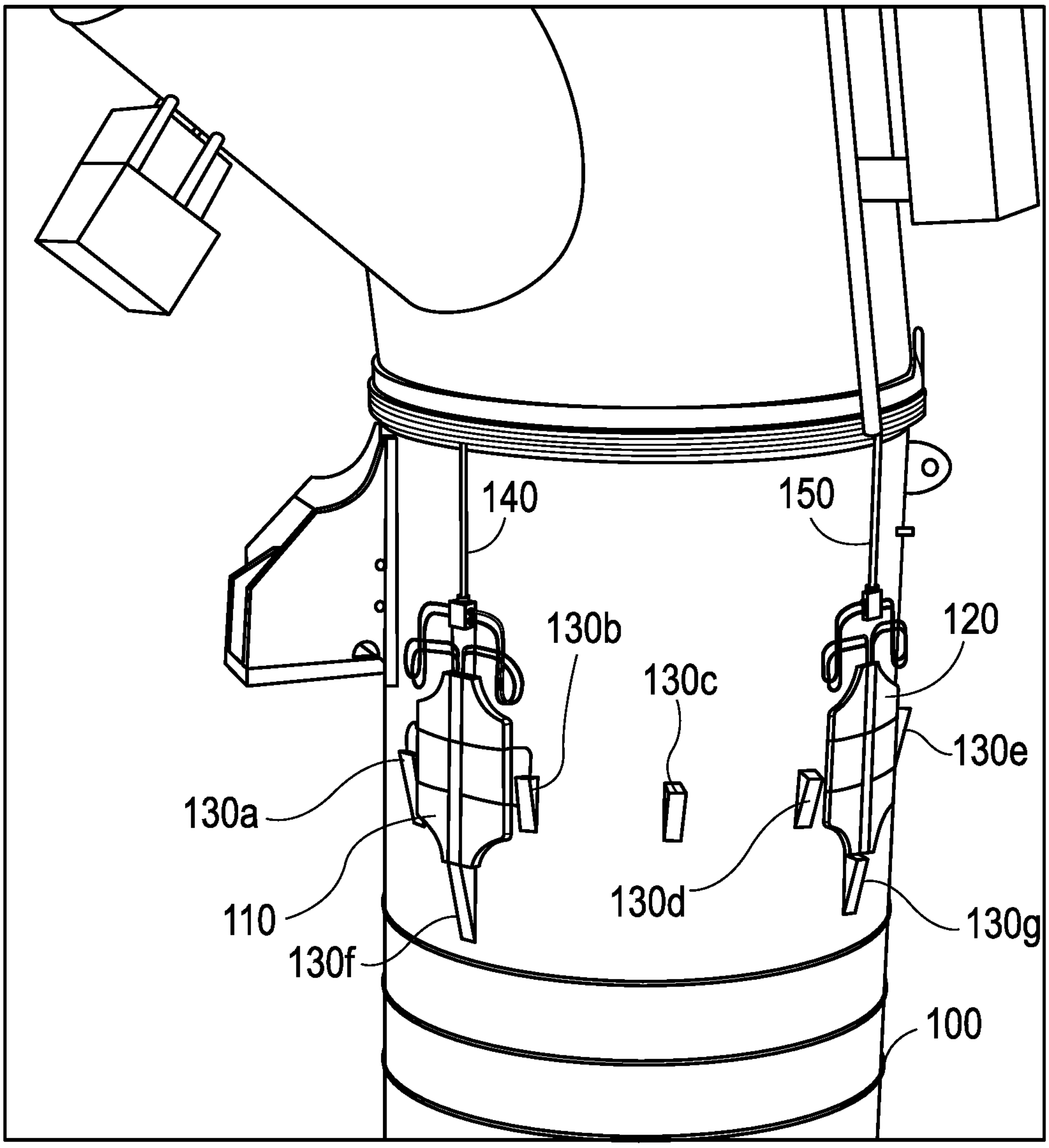

FIG. 2

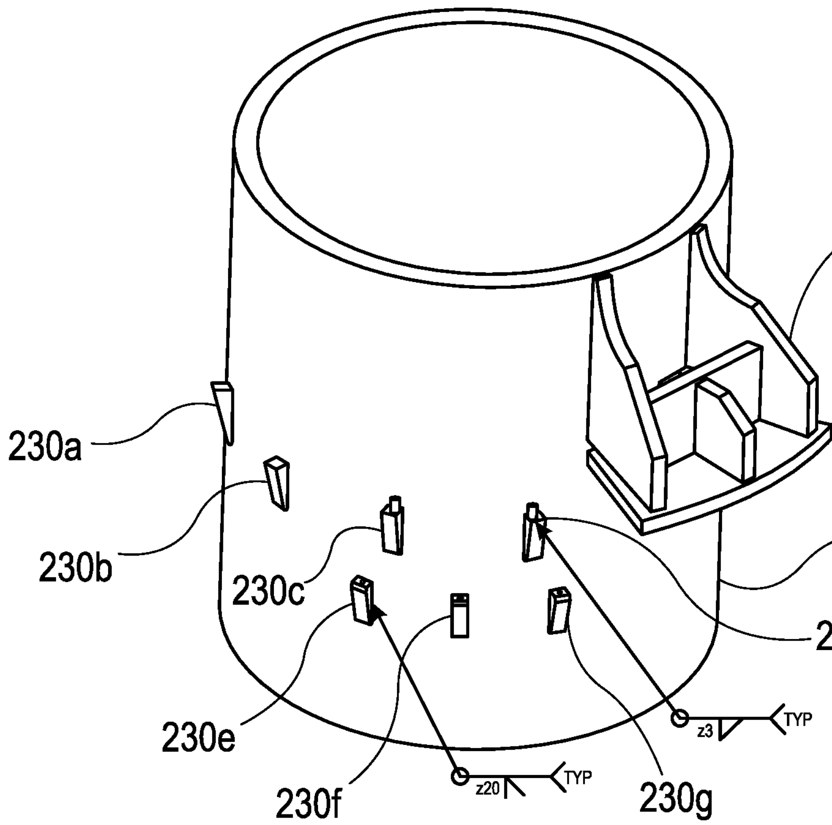
240
230a
200
230b
230c
230d
z3
TYP
230e
z20
TYP
230g
230f

FIG. 3

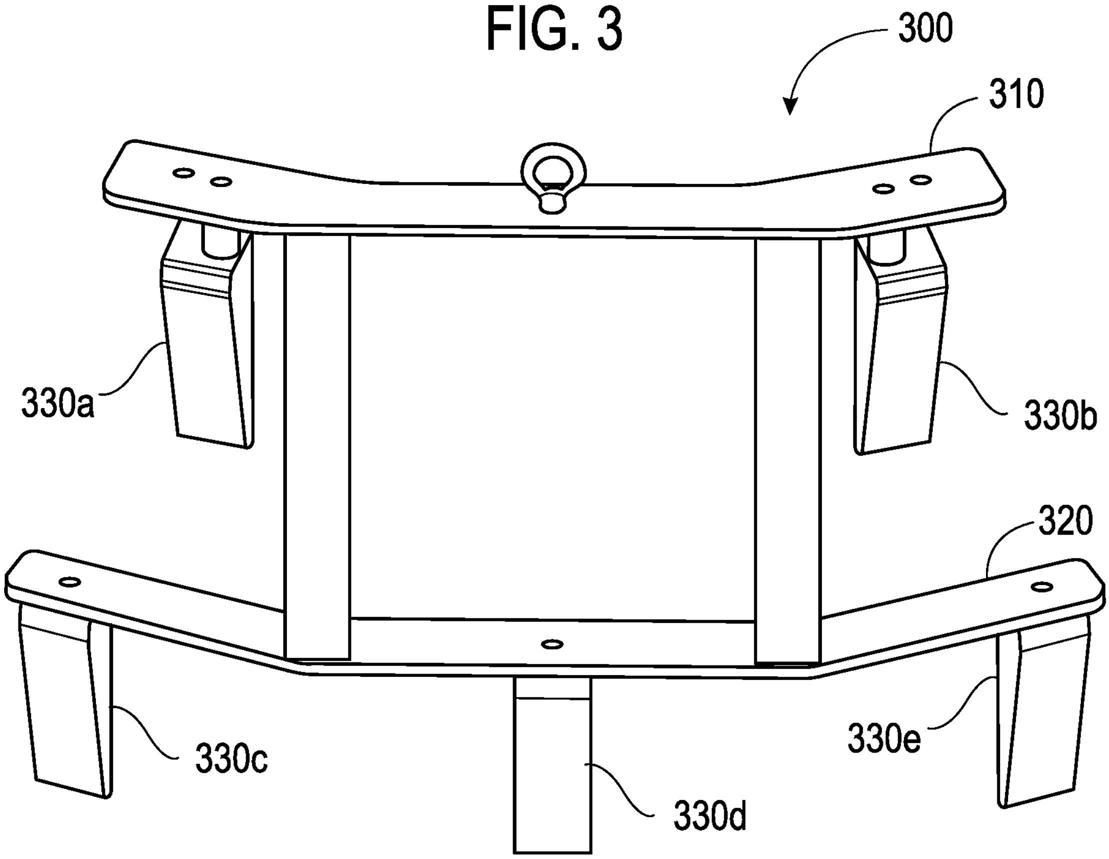
300
310
330a
330b
320
330e
330c
330d

FIG. 4

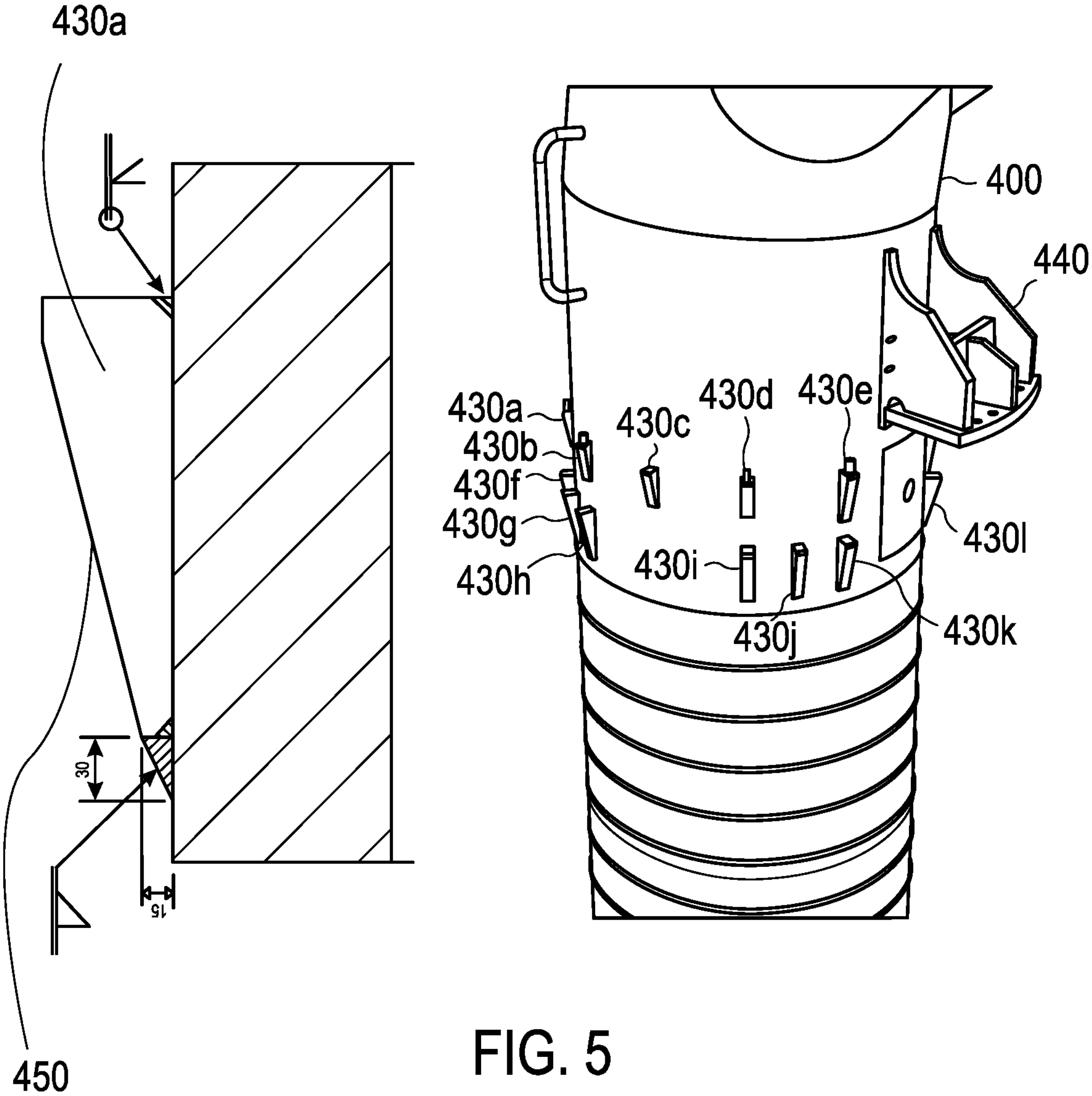
430a
30
15
450
400
440
430a
430b
430c
430d
430e
430f
430g
430h
430i
430j
430k
430l

FIG. 5

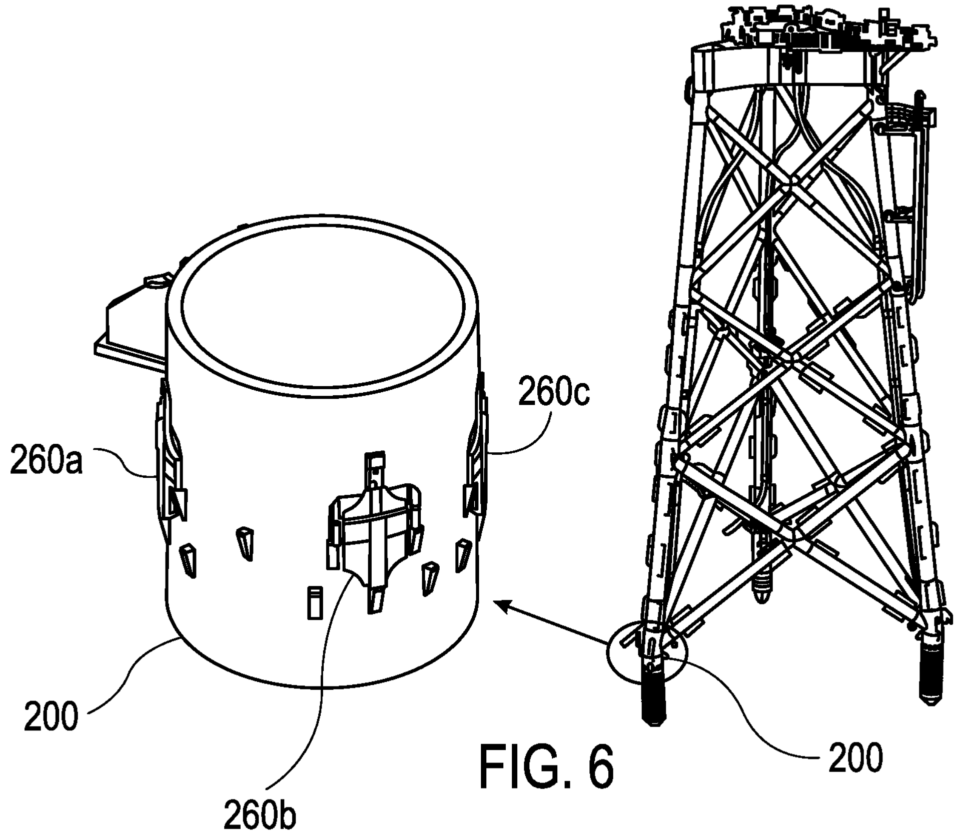

FIG. 6

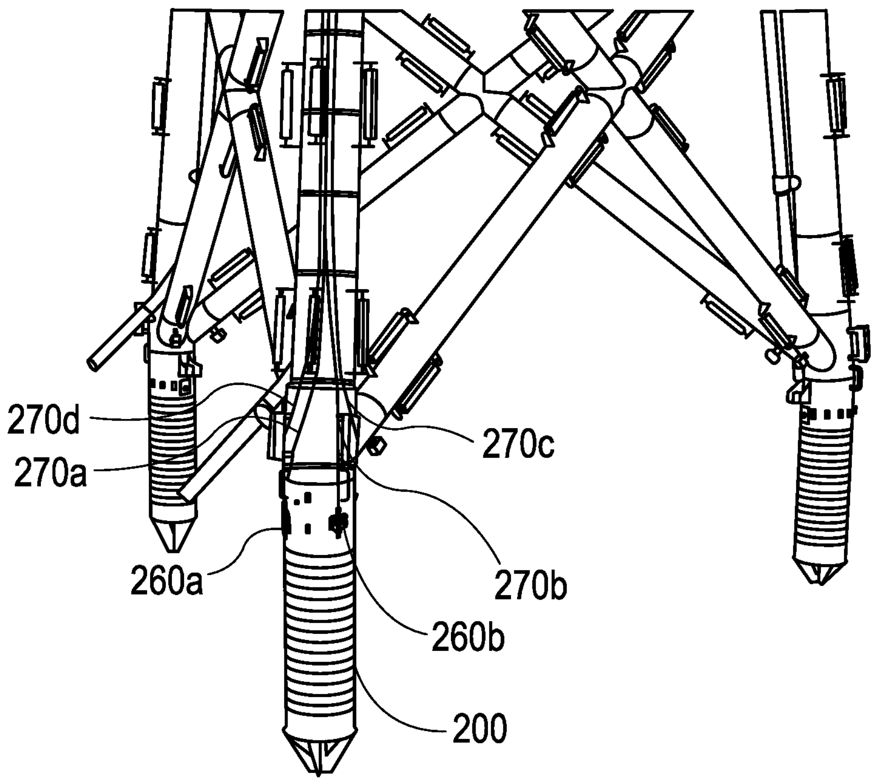

FIG. 7

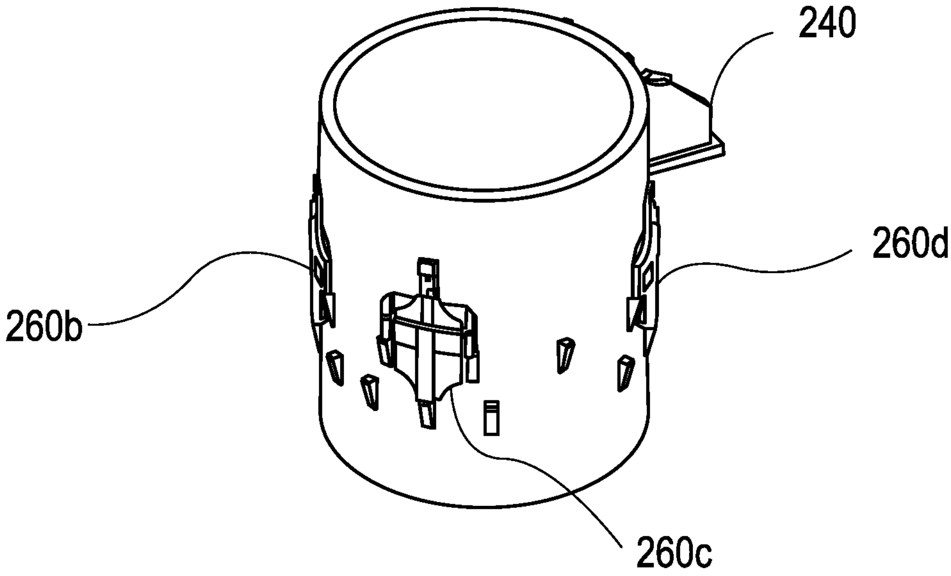

FIG. 8a

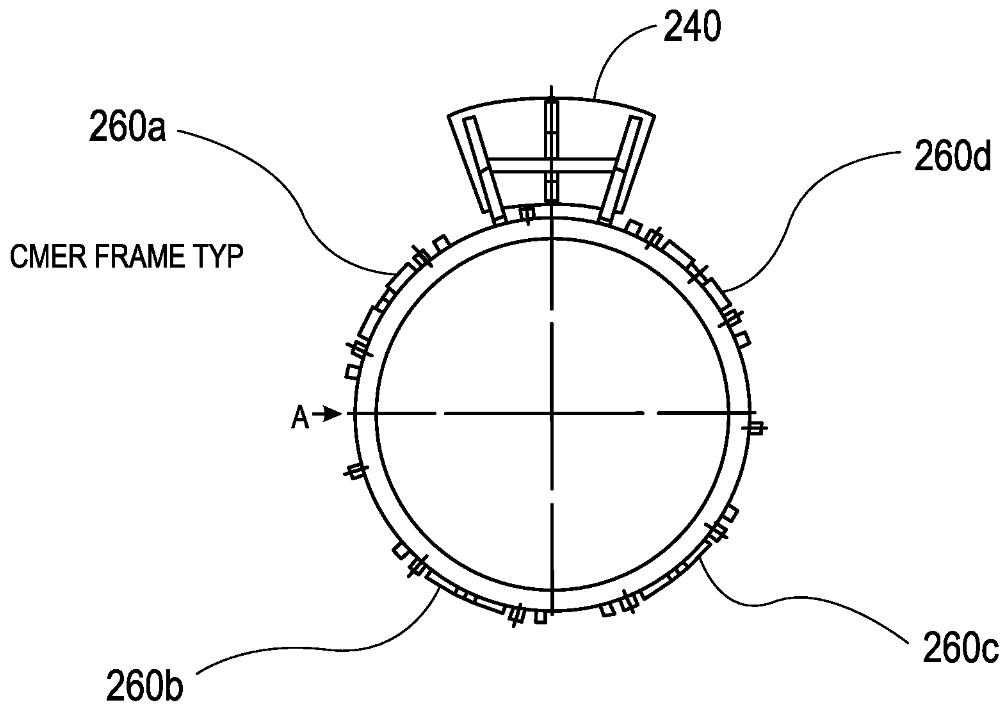

FIG. 8b

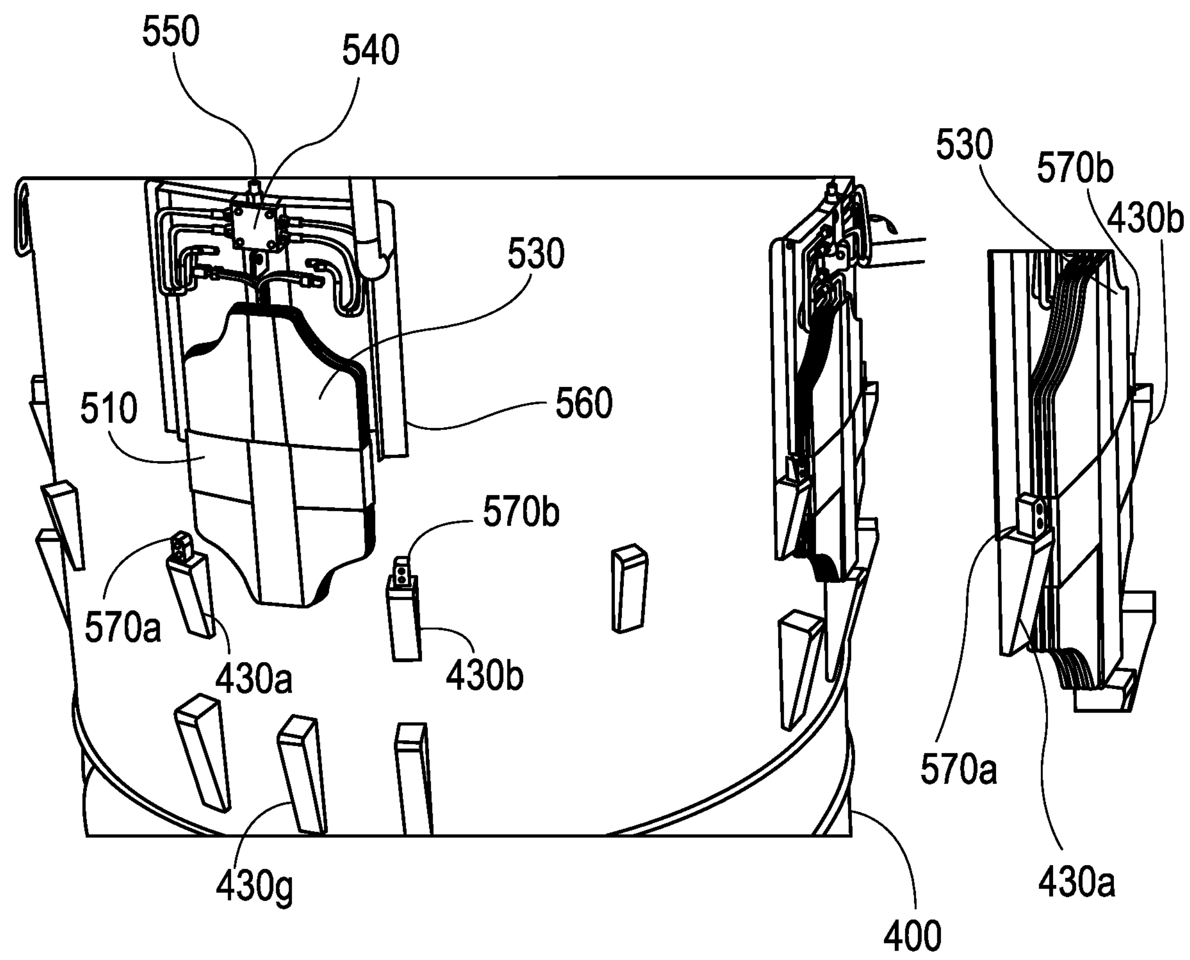
550
540
530
510
560
570b
570a
430a
430b
430g
400
530
570b
430b
570a
430a

FIG. 9

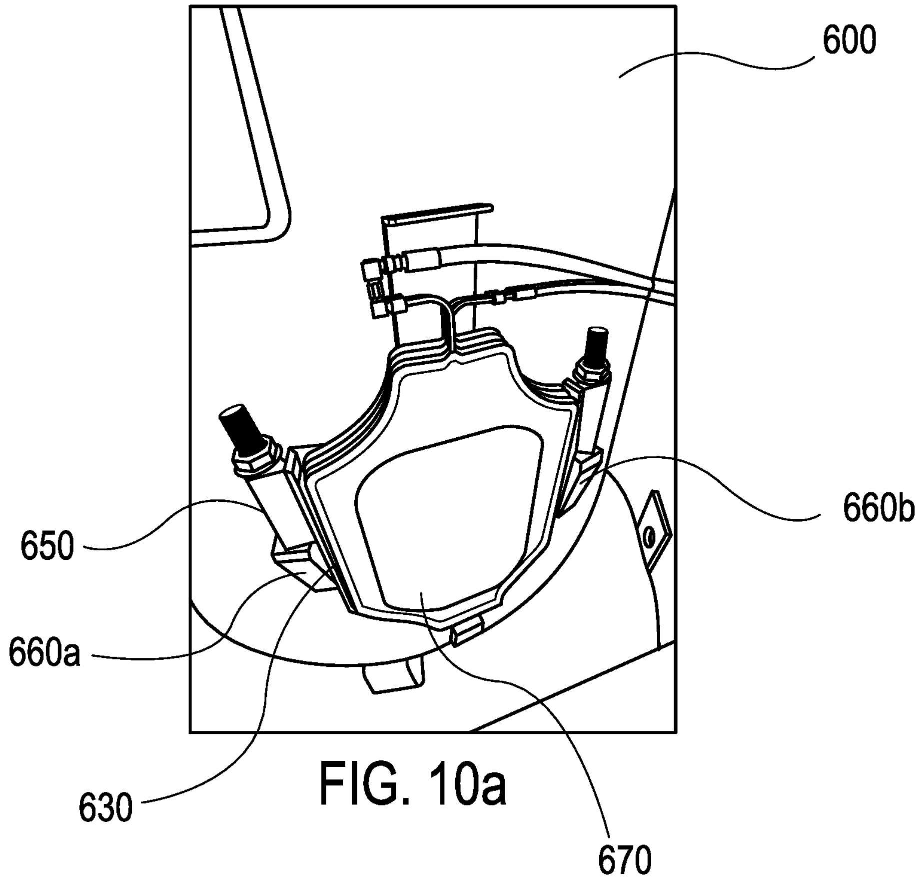

FIG. 10a

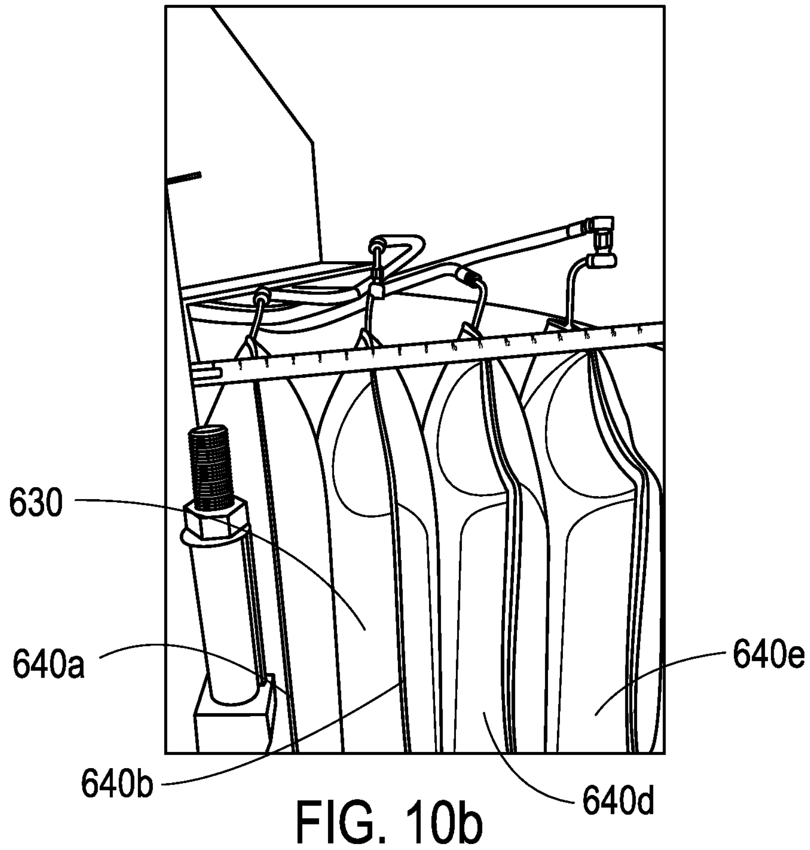

FIG. 10b

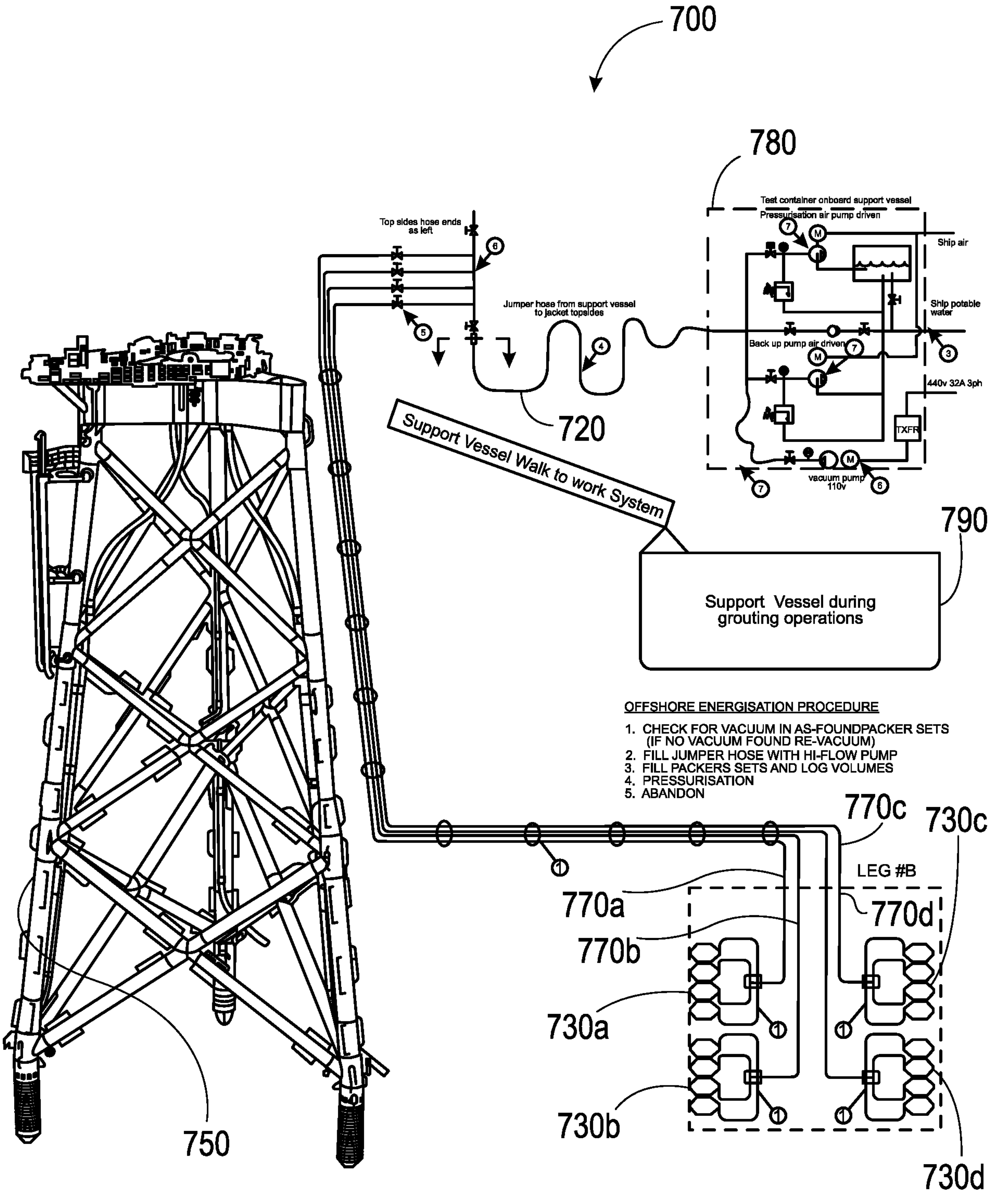
700
780
Test container onboard support vessel
Pressurisation air pump driven
Ship air
Ship potable water
Back up pump air driven
440v 32A 3ph
TXFR
vacuum pump 110v
Top sides hose ends as left
Jumper hose from support vessel to jacket topsides
720
Support Vessel Walk to work System
790
Support Vessel during grouting operations
OFFSHORE ENERGISATION PROCEDURE
1. CHECK FOR VACUUM IN AS-FOUNDPACKER SETS (IF NO VACUUM FOUND RE-VACUUM)
2. FILL JUMPER HOSE WITH HI-FLOW PUMP
3. FILL PACKERS SETS AND LOG VOLUMES
4. PRESSURISATION
5. ABANDON
770c
730c
LEG #B
770a
770d
770b
730a
730b
730d
750

FIG. 11

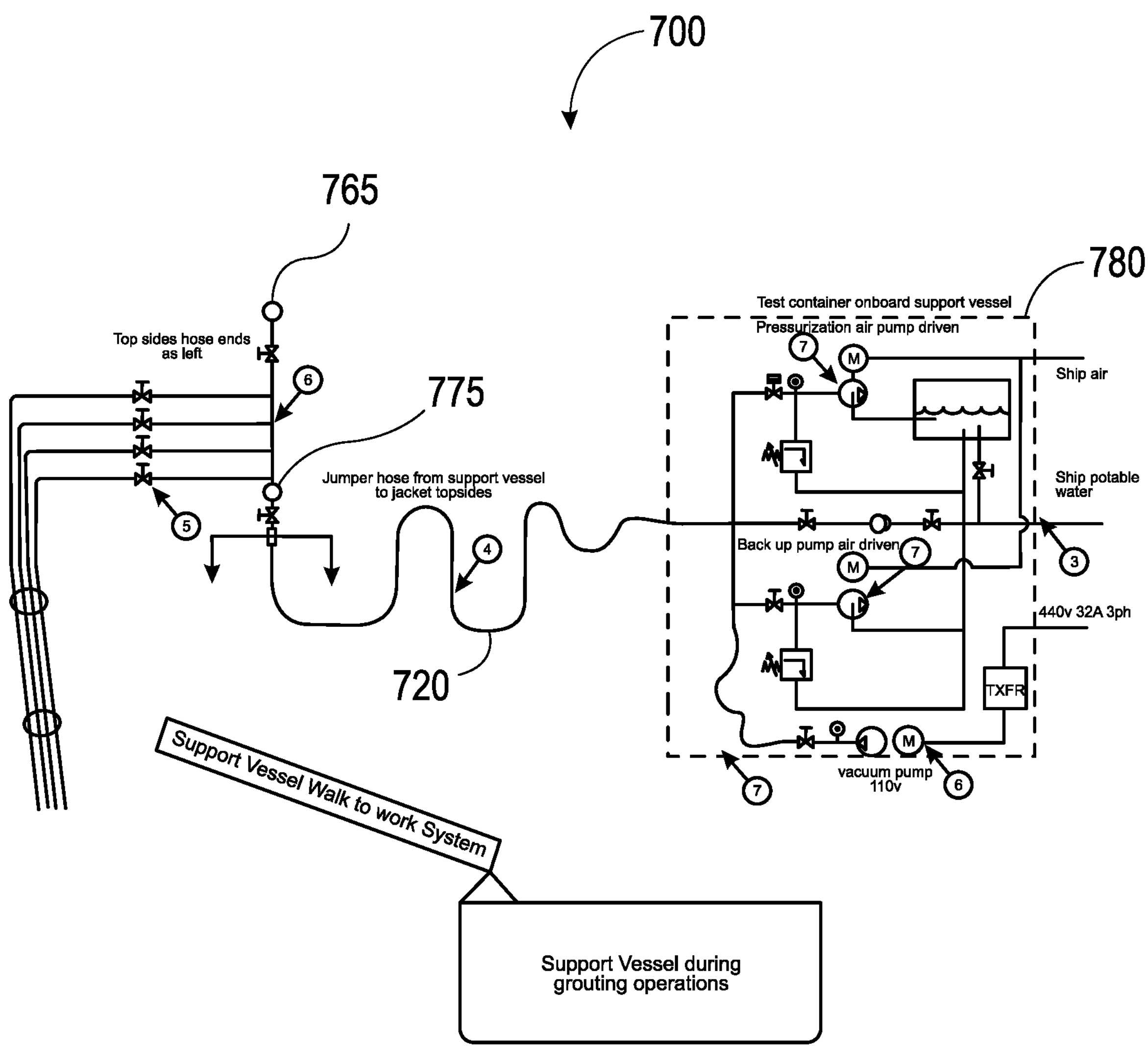
700
765
780
775
720
Top sides hose ends
as left
Jumper hose from support vessel
to jacket topsides
Test container onboard support vessel
Pressurization air pump driven
Ship air
Ship potable
water
Back up pump air driven
440v 32A 3ph
TXFR
vacuum pump
110v
Support Vessel Walk to work System
Support Vessel during
grouting operations
M
3
4
5
6
7

FIG. 12

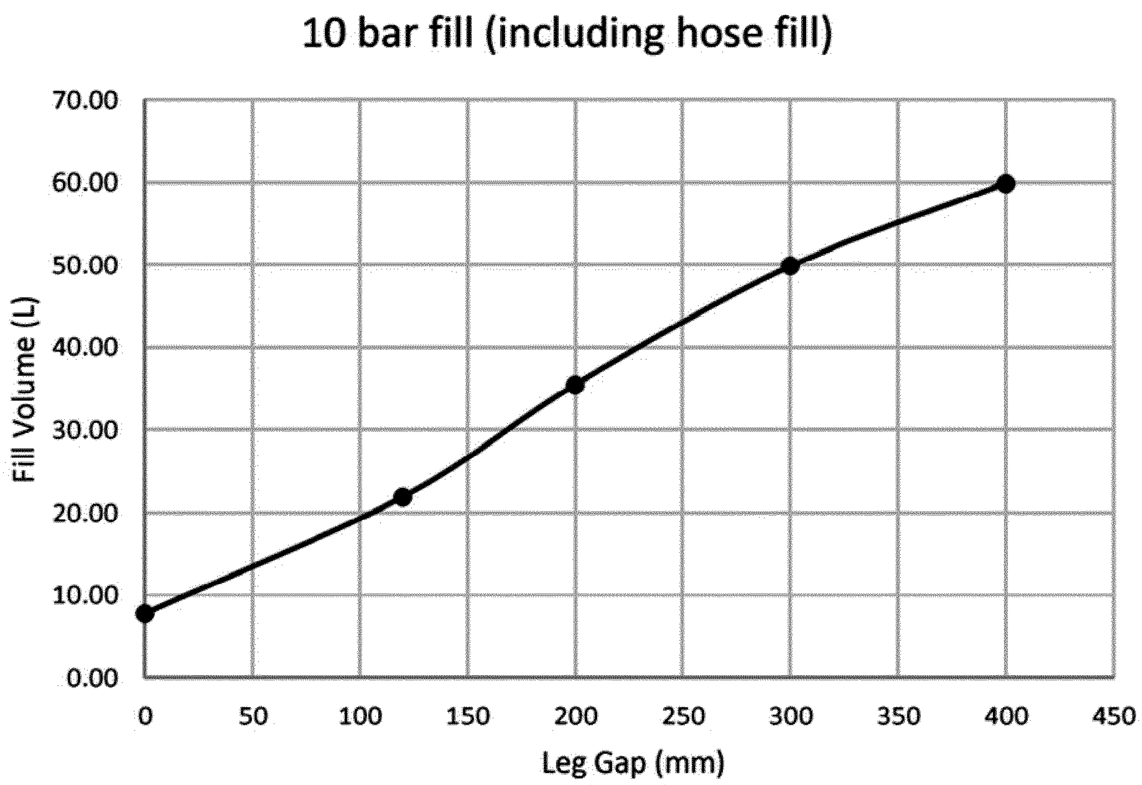
10 bar fill (including hose fill)
Fill Volume (L)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
50
100
150
200
250
300
350
400
450
Leg Gap (mm)

FIG. 13

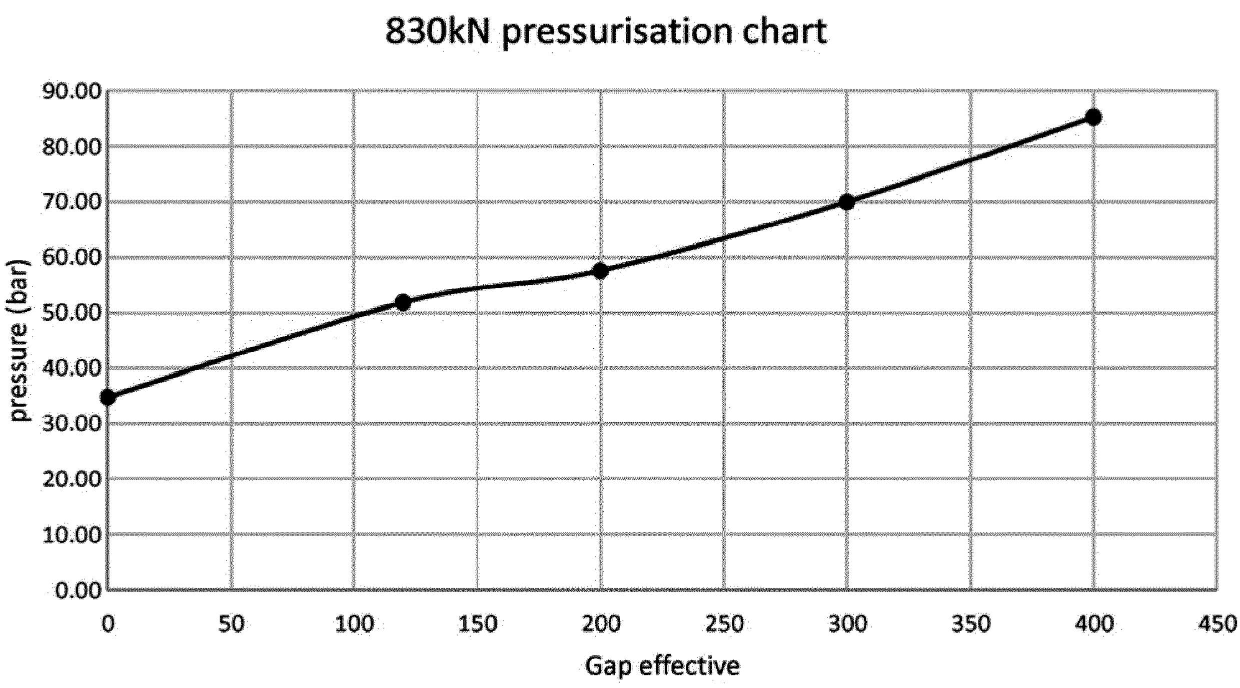
830kN pressurisation chart
pressure (bar)
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
50
100
150
200
250
300
350
400
450
Gap effective

FIG. 14

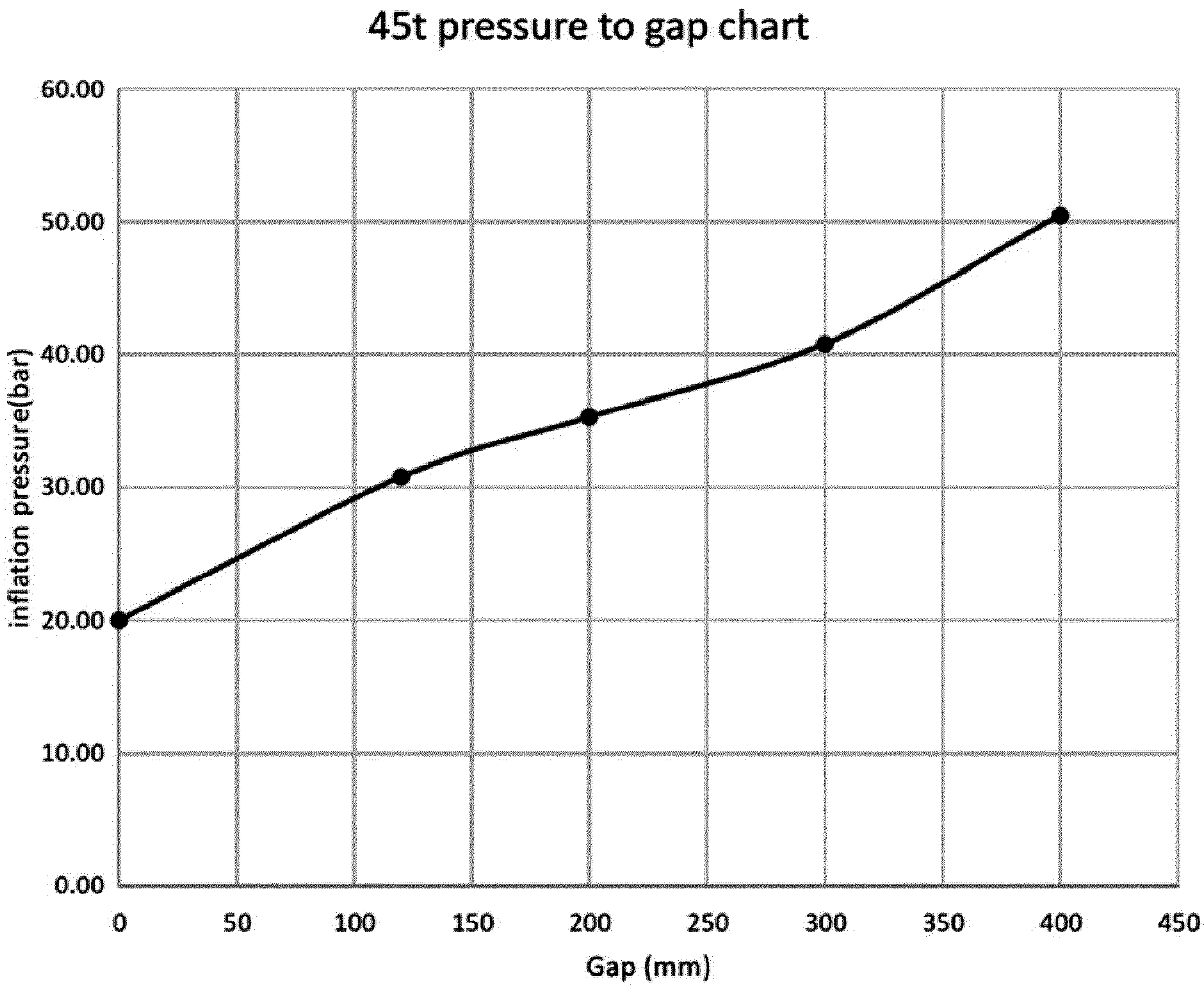
45t pressure to gap chart
60.00
50.00
40.00
30.00
20.00
10.00
0.00
inflation pressure(bar)
0
50
100
150
200
250
300
350
400
450
Gap (mm)

FIG. 15

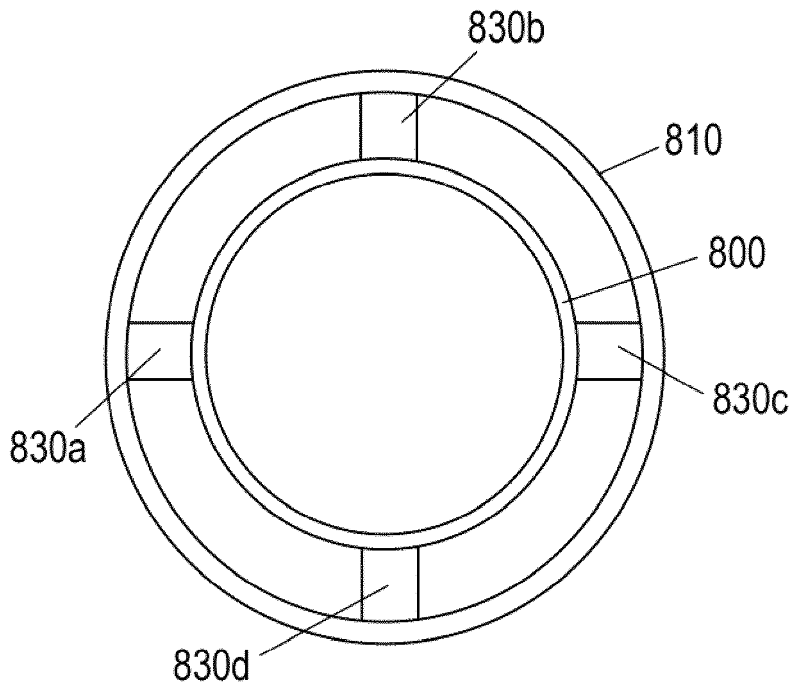

FIG. 16a

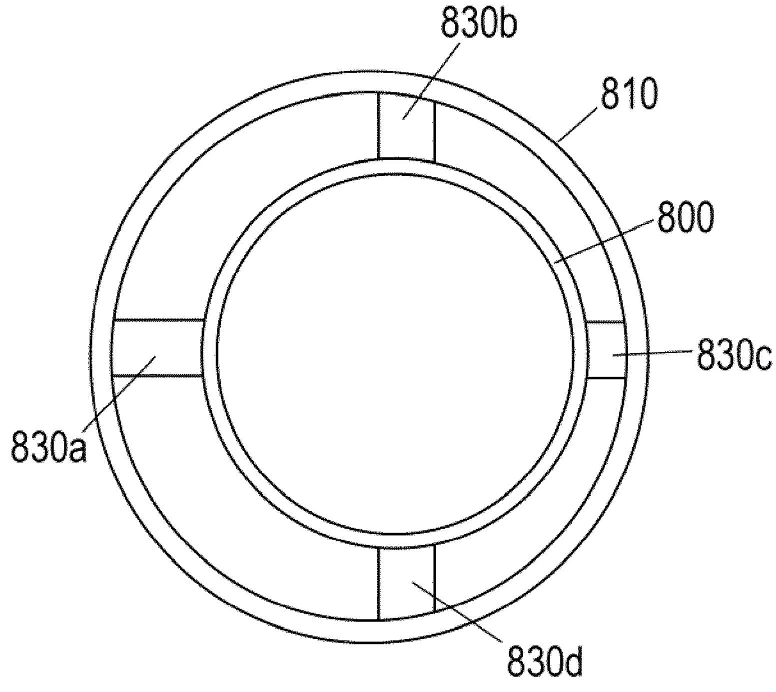

FIG. 16b

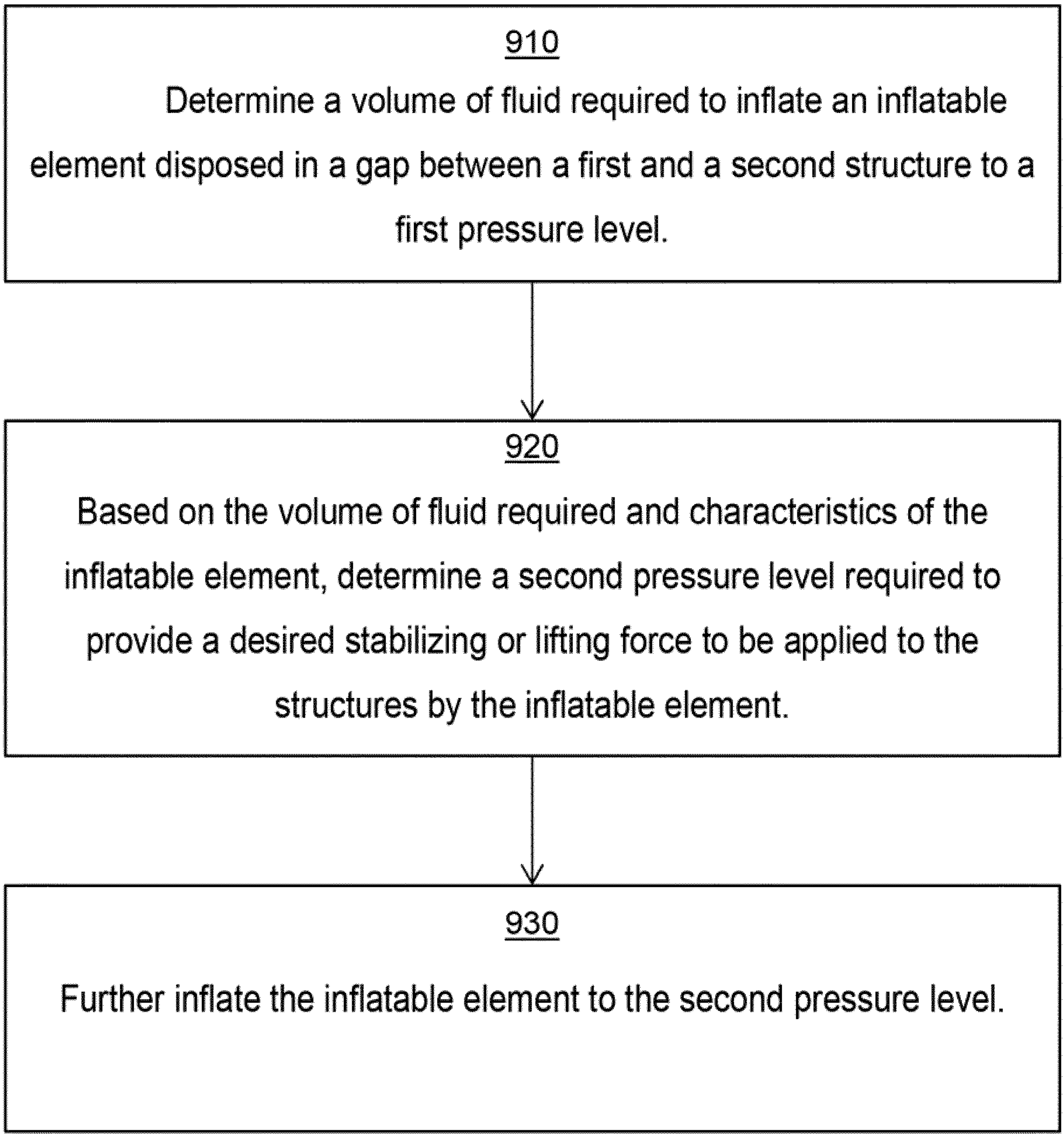
910
Determine a volume of fluid required to inflate an inflatable element disposed in a gap between a first and a second structure to a first pressure level.
920
Based on the volume of fluid required and characteristics of the inflatable element, determine a second pressure level required to provide a desired stabilizing or lifting force to be applied to the structures by the inflatable element.
930
Further inflate the inflatable element to the second pressure level.

FIG. 17

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- GB 1814224 A **[0005] [0082] [0085] [0088]**