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(54) METHOD OF ASSEMBLING AND DEPLOYING A FLOATING OFFSHORE WIND TURBINE PLATFORM

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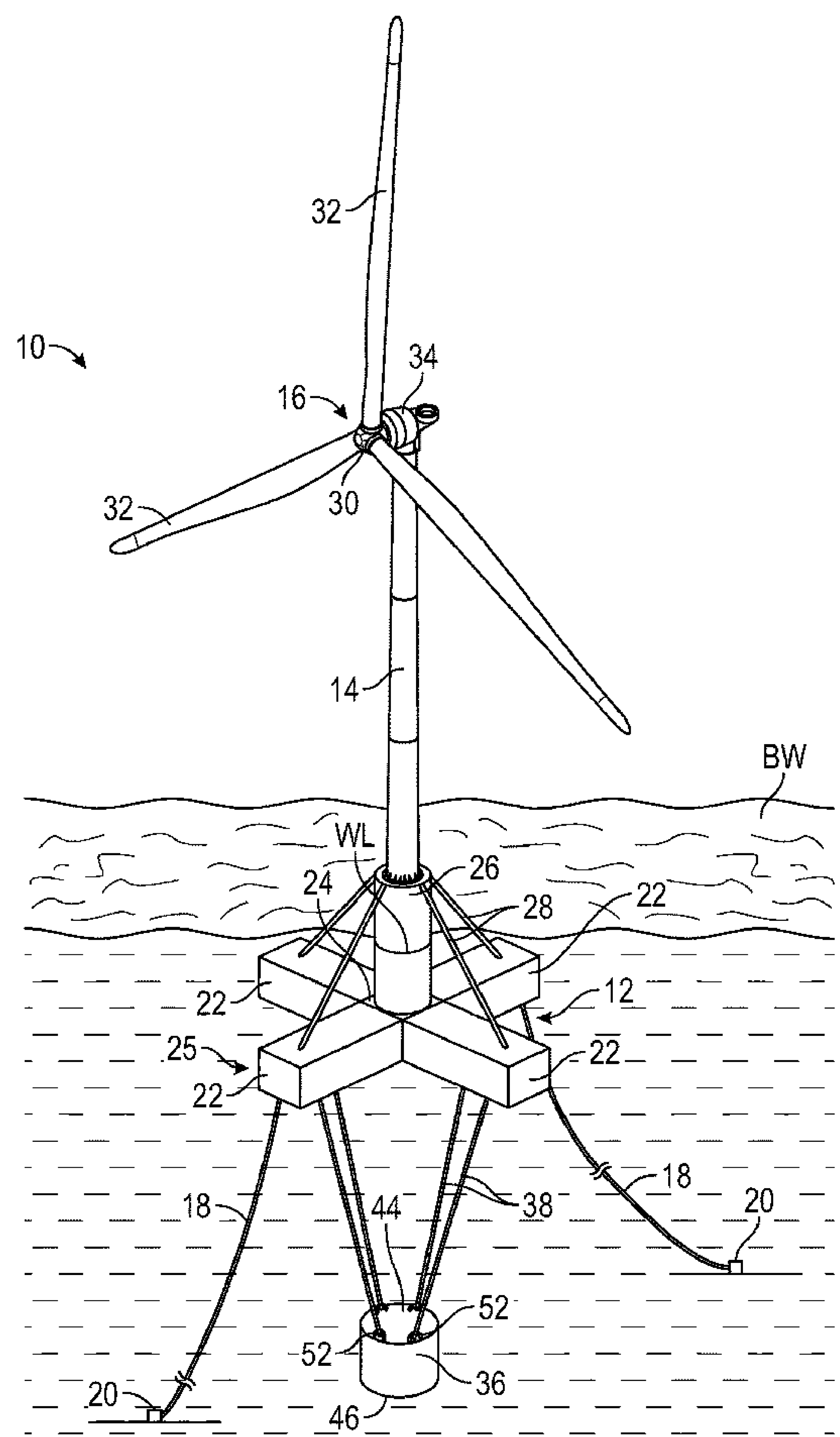
CPC ***B63B 77/10*** (2020.01); ***B63B 1/107*** (2013.01); ***B63B 21/50*** (2013.01); ***F03D 13/25*** (2016.05); *B63B 2001/044* (2013.01)

(57) **ABSTRACT**

A method of assembling and deploying a floating offshore wind turbine (FOWT) platform includes floating a buoyant floater and a hollow outer tank in a floating assembly, placing permanent ballast material in the outer tank to define a mass, and sinking the mass to a seabed. The buoyant floater is moved to a position over the mass. Transit lines are attached between a lifting device in the buoyant floater and the mass to define a FOWT platform. The mass is lifted to a point directly under the buoyant floater and the FOWT platform is towed to an installation site. Mooring lines are attached between anchors in the seabed and the buoyant floater, and the mass is lowered to a depth wherein suspension lines attached thereto are taught, the mass with the suspension lines defining a suspended mass. The transit lines are then stored or removed from the mass.



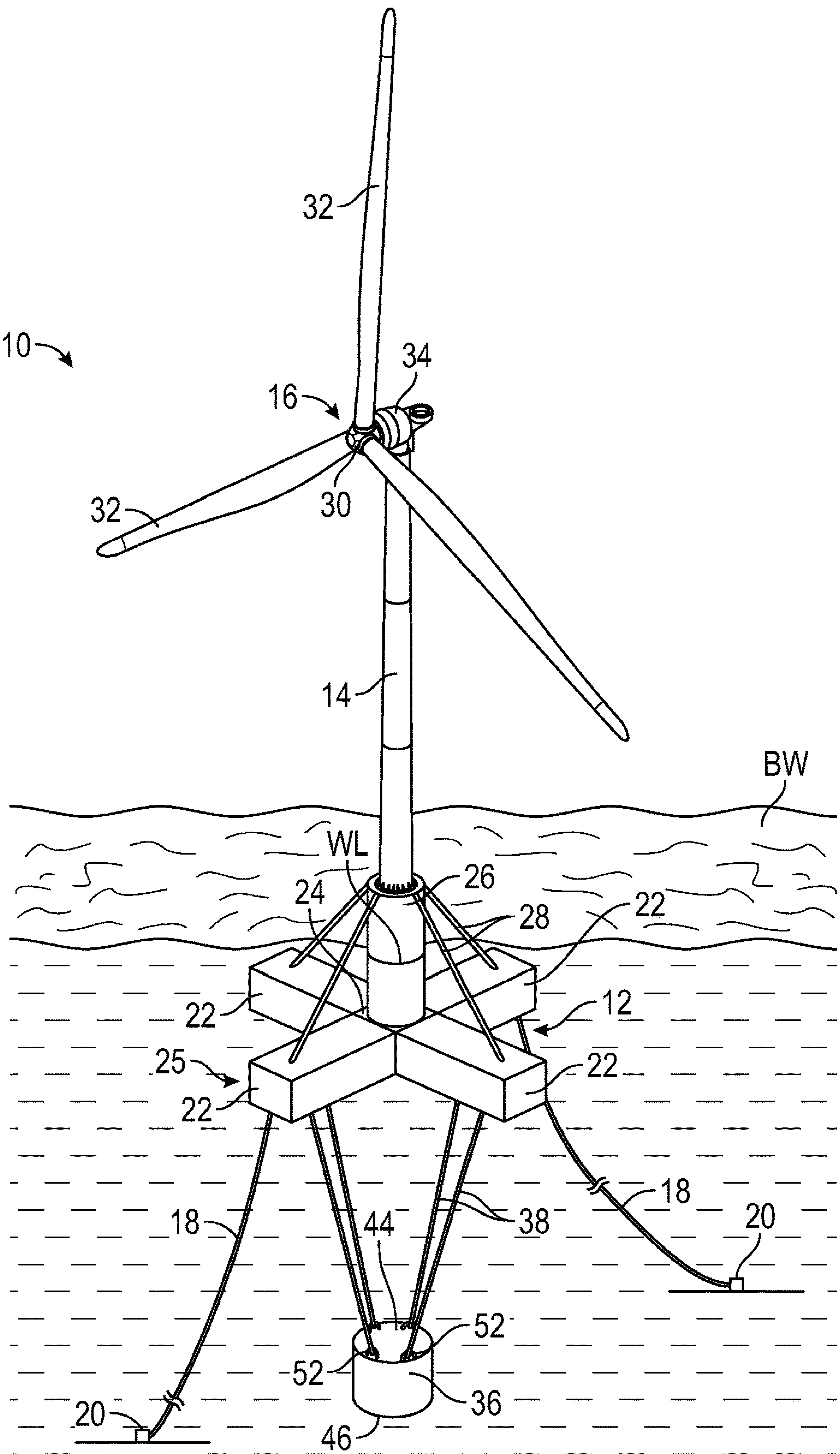

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FIG. 1

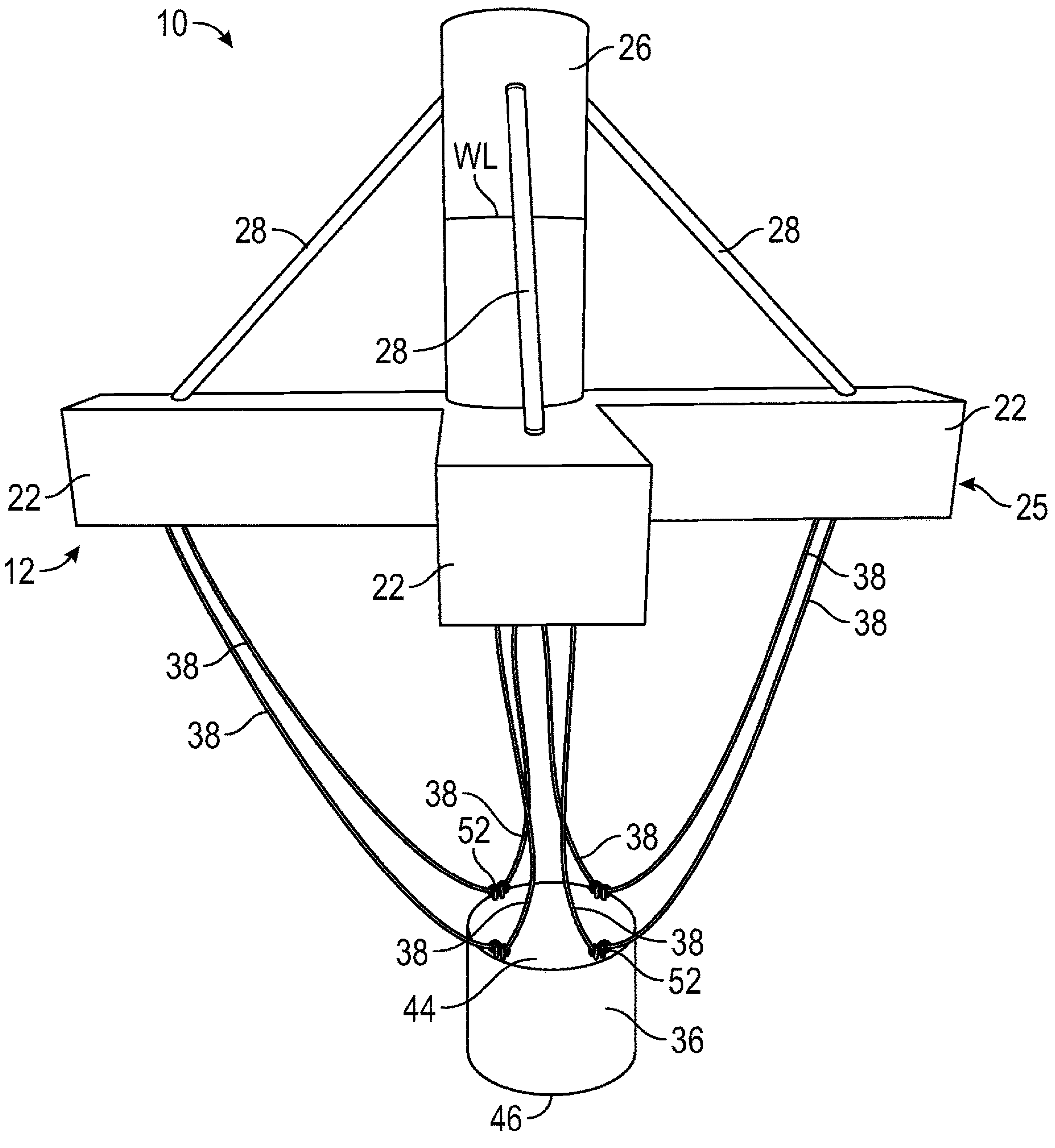

FIG. 2

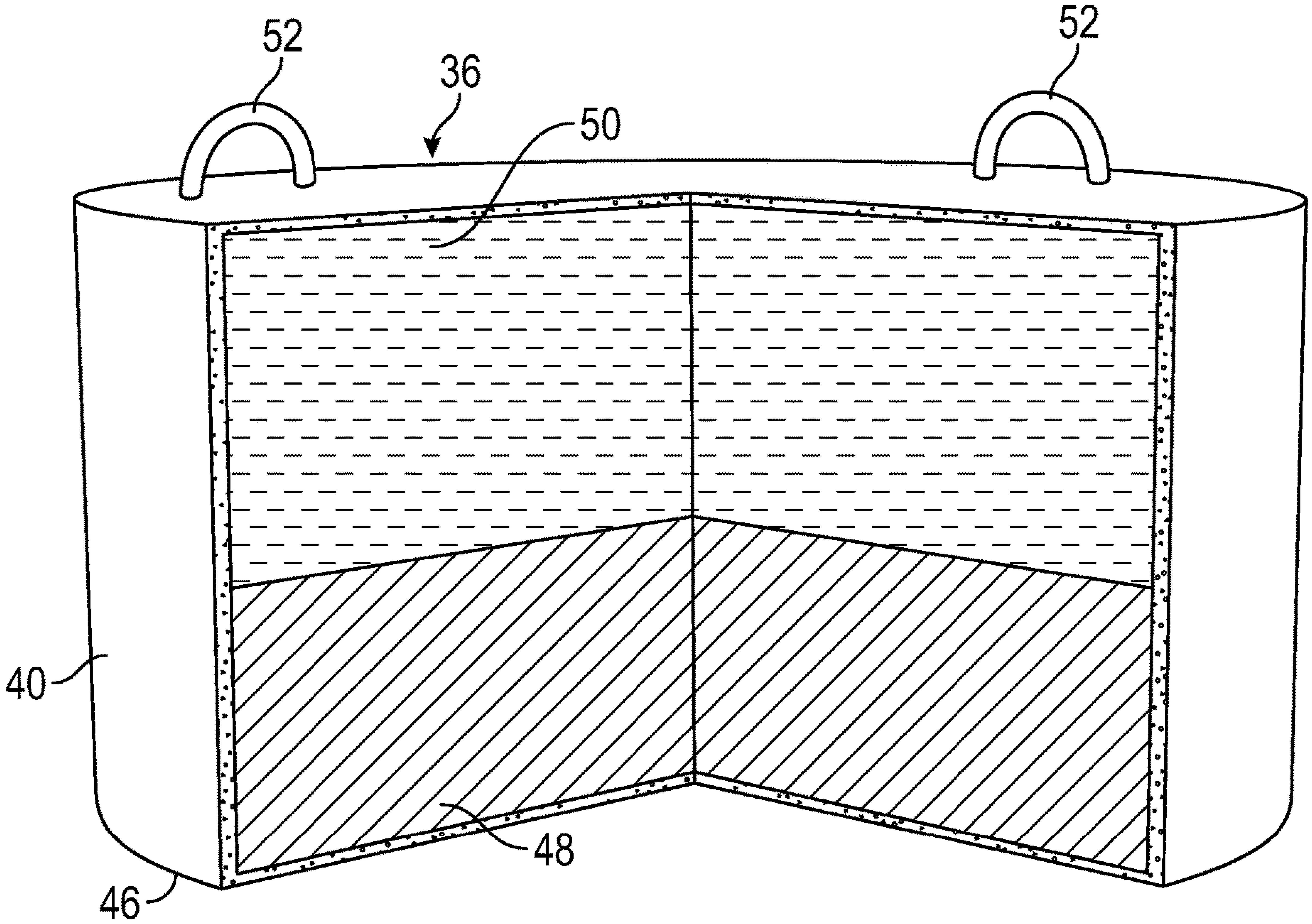

FIG. 3

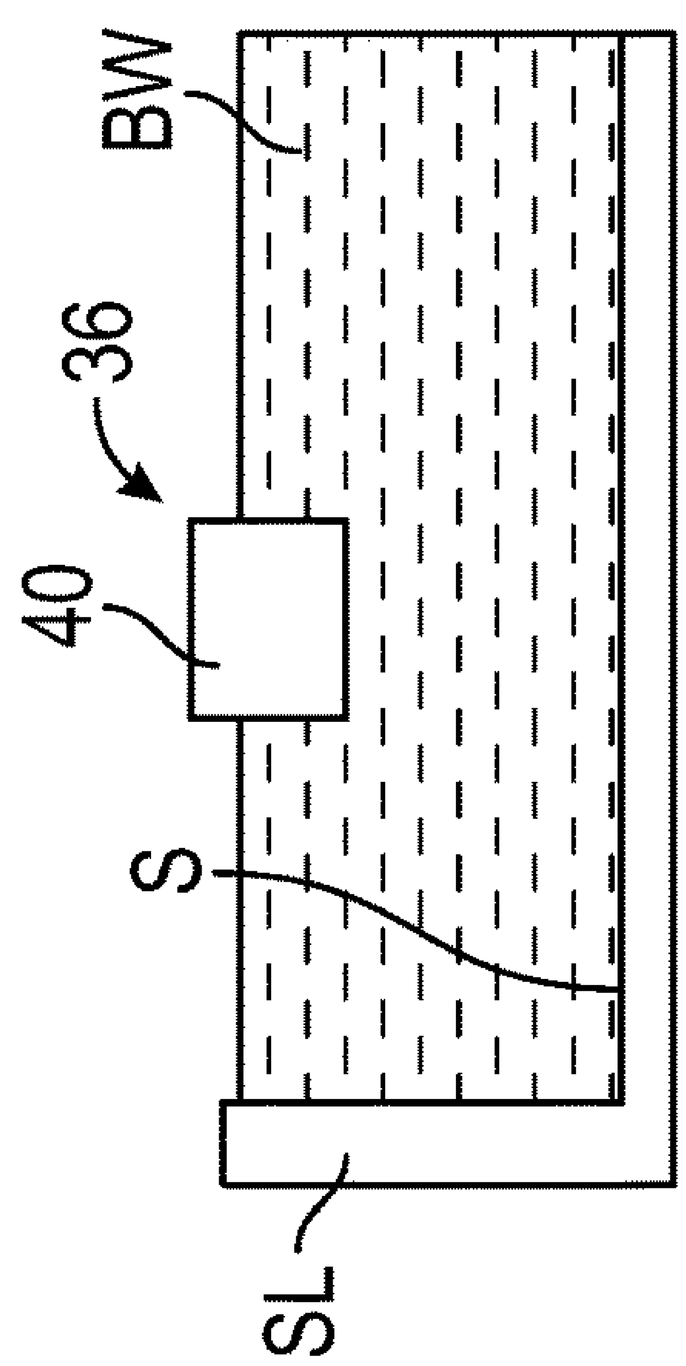

FIG. 4A

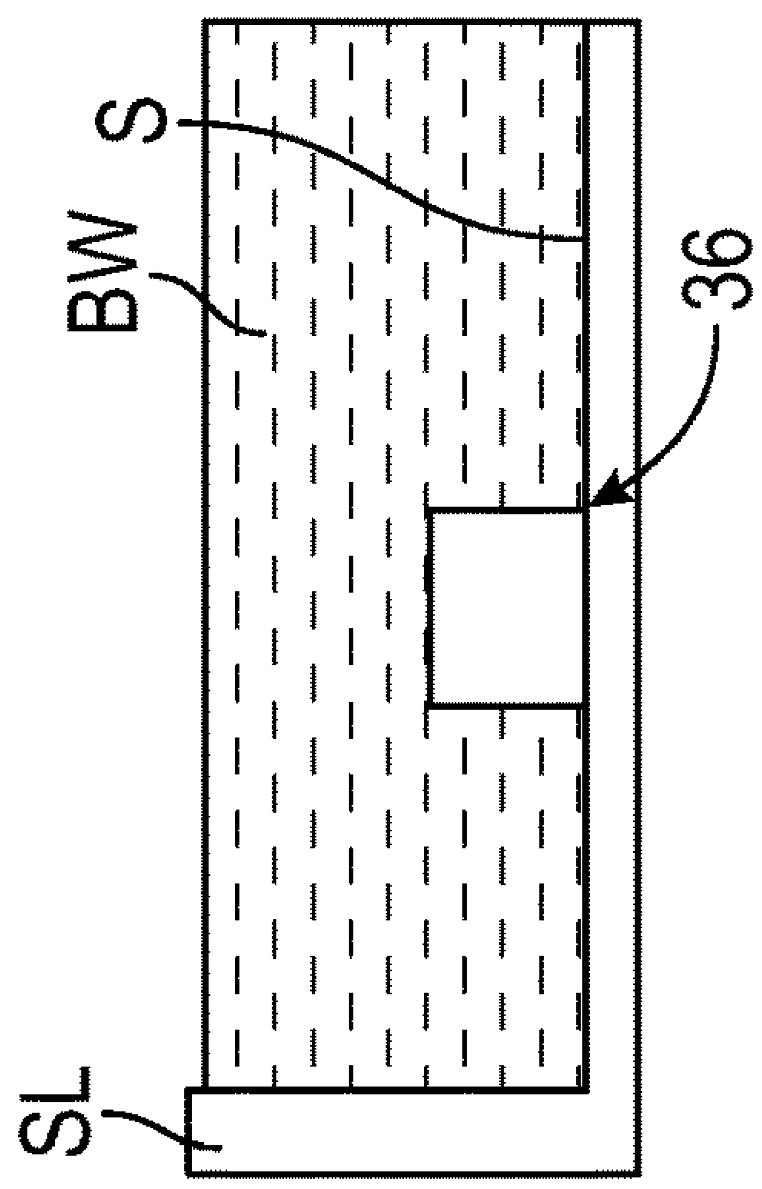

FIG. 4B

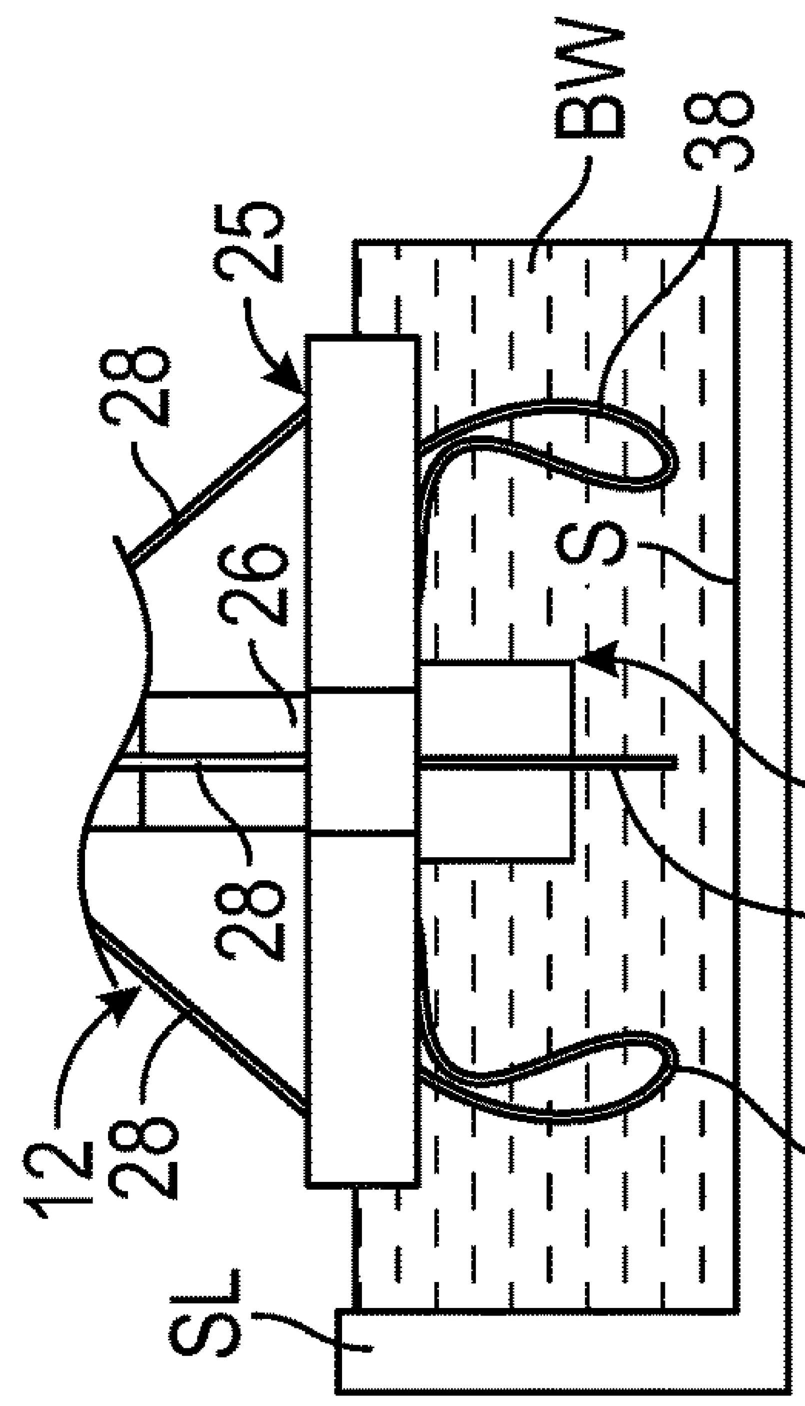

FIG. 4C

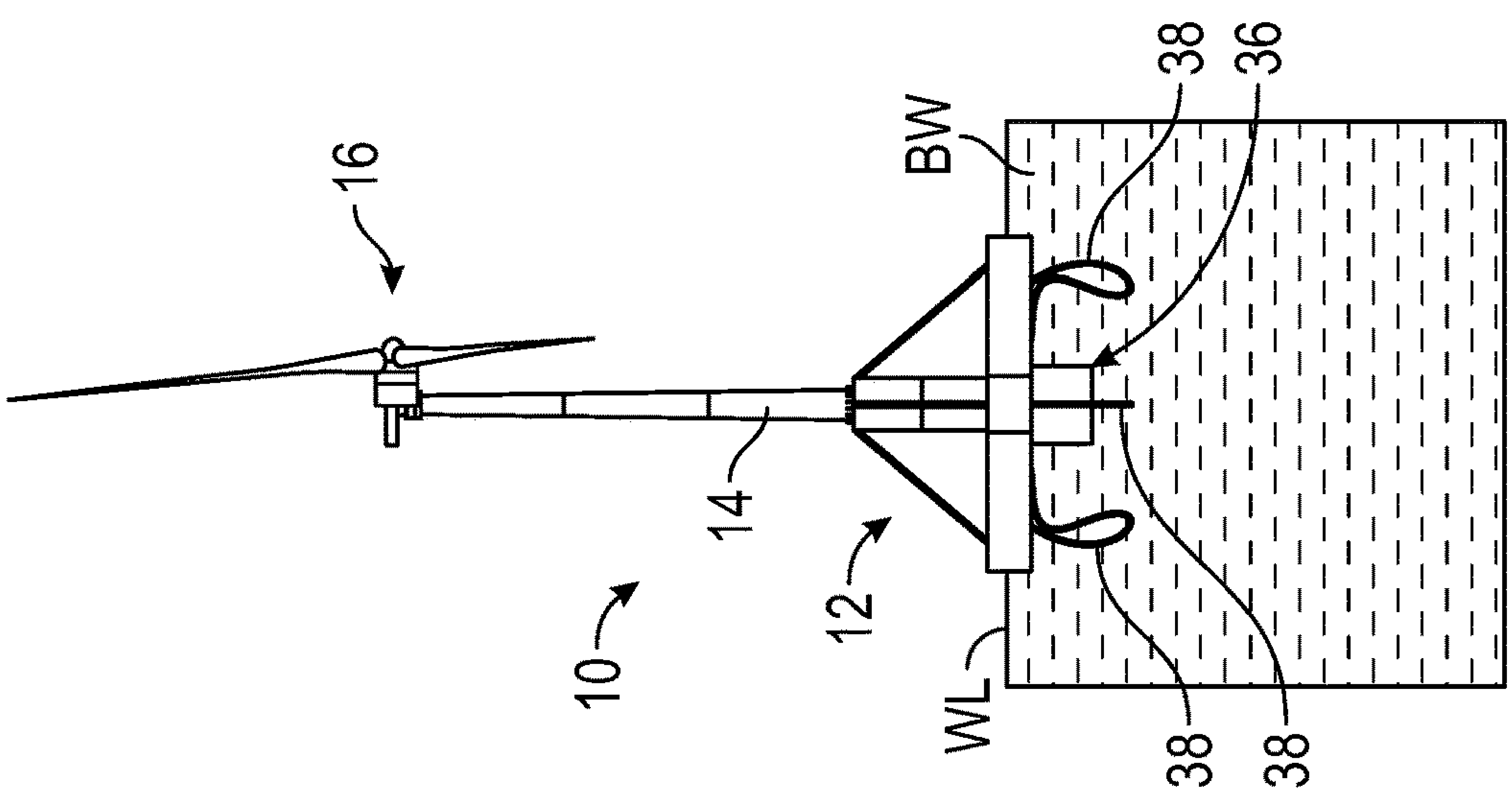

FIG. 4D

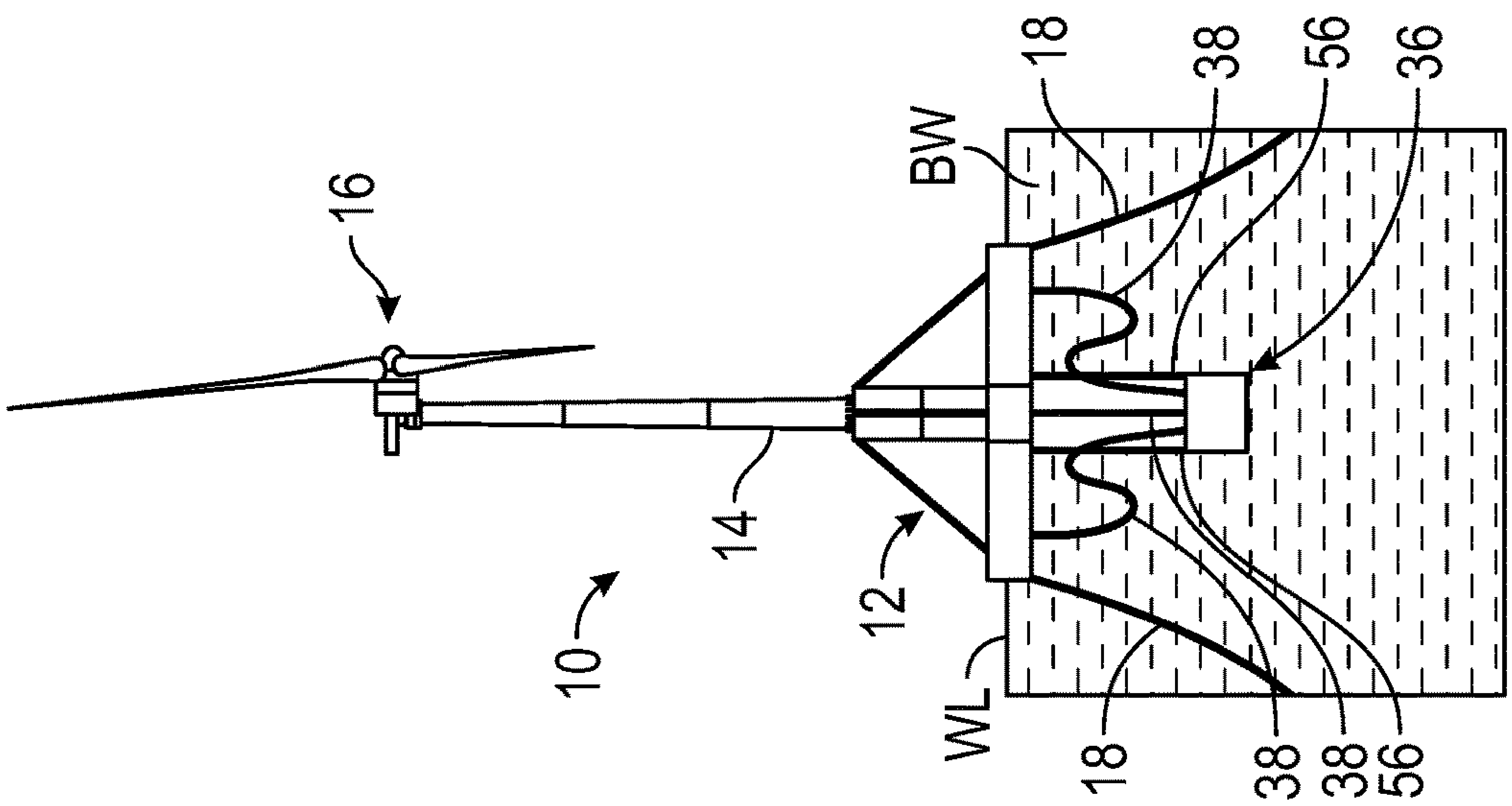

FIG. 4E

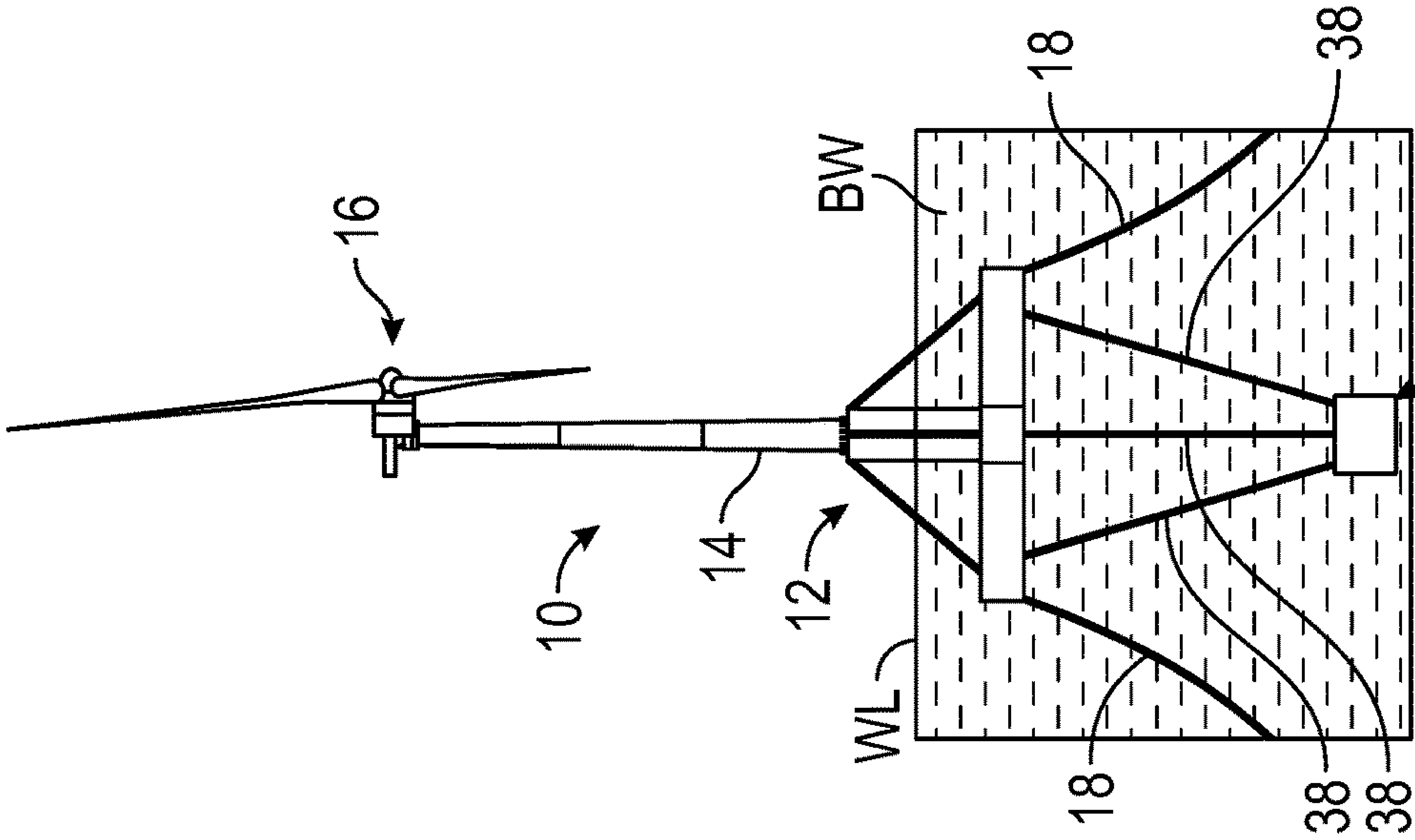

FIG. 4F

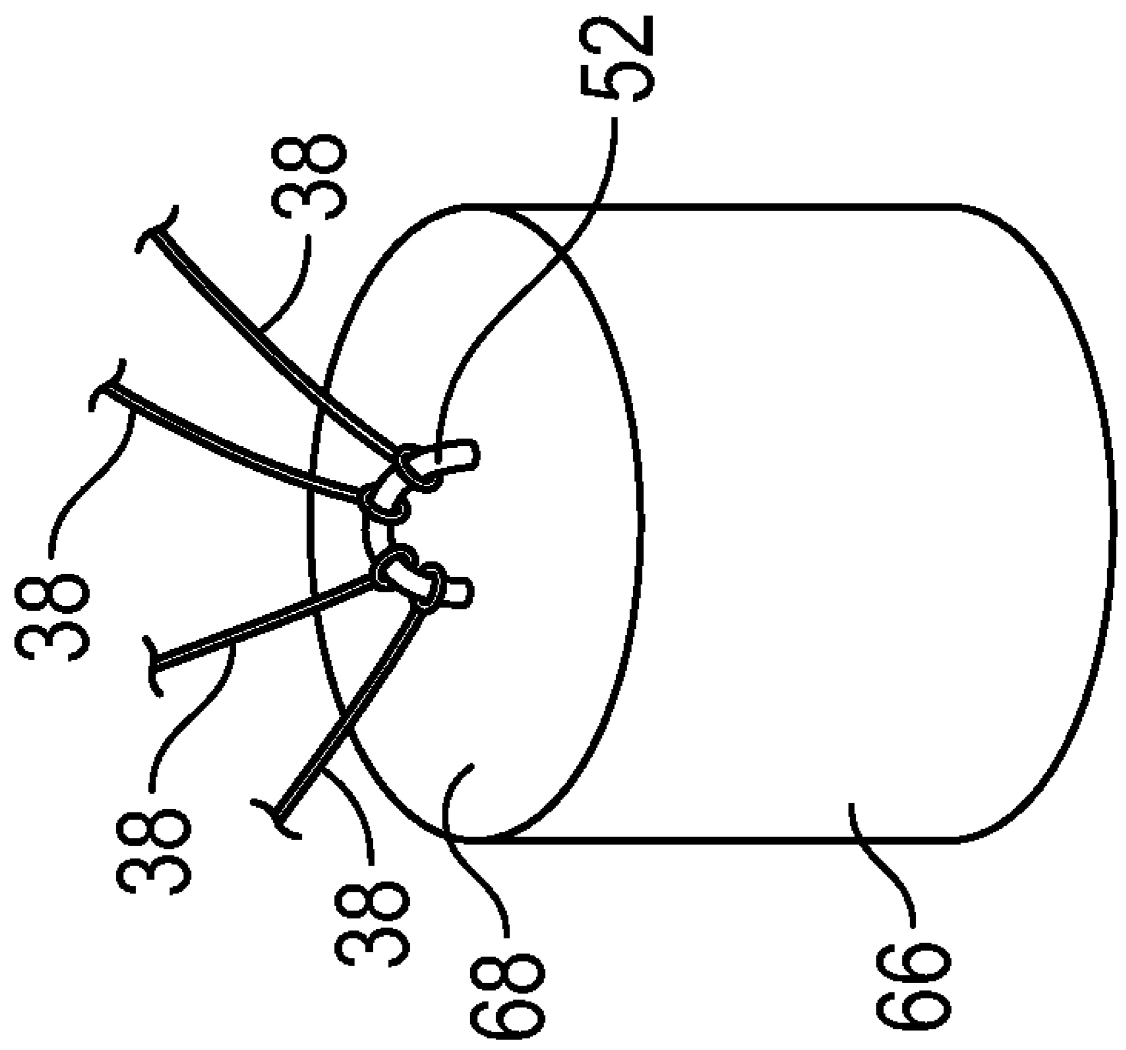

FIG. 6

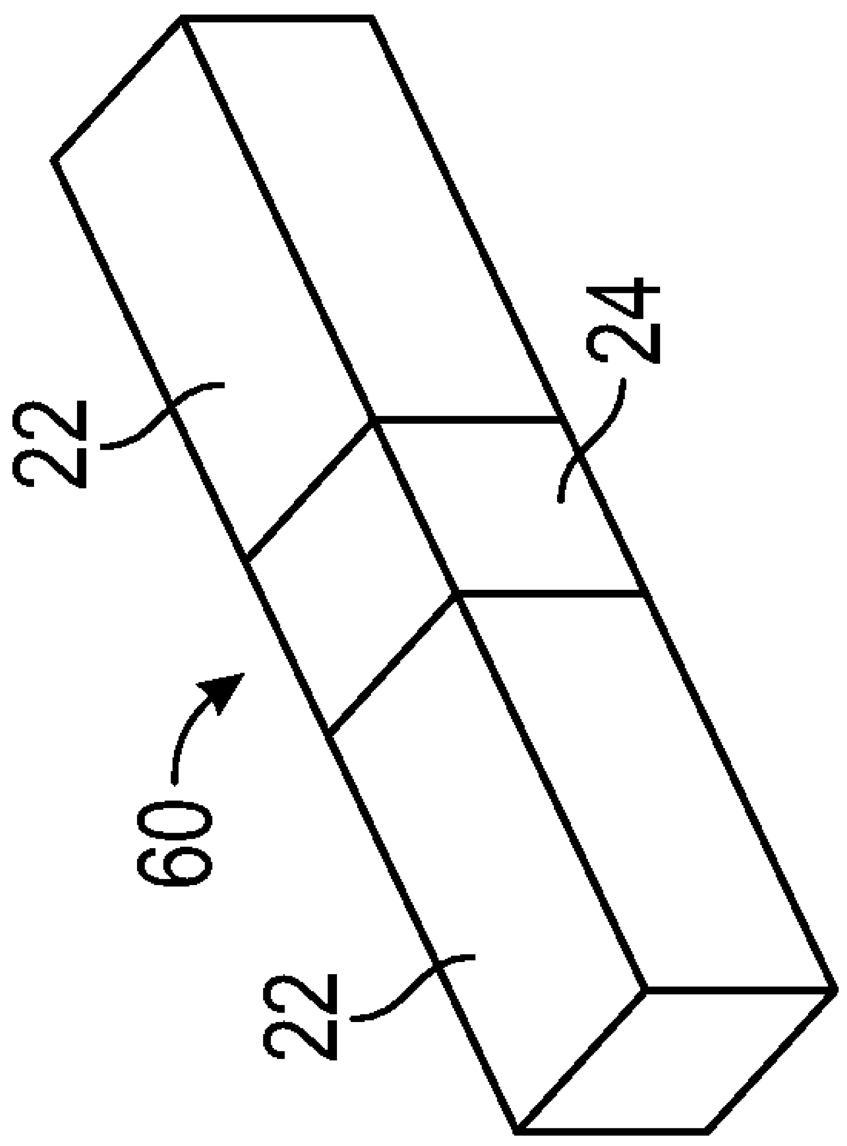

FIG. 7

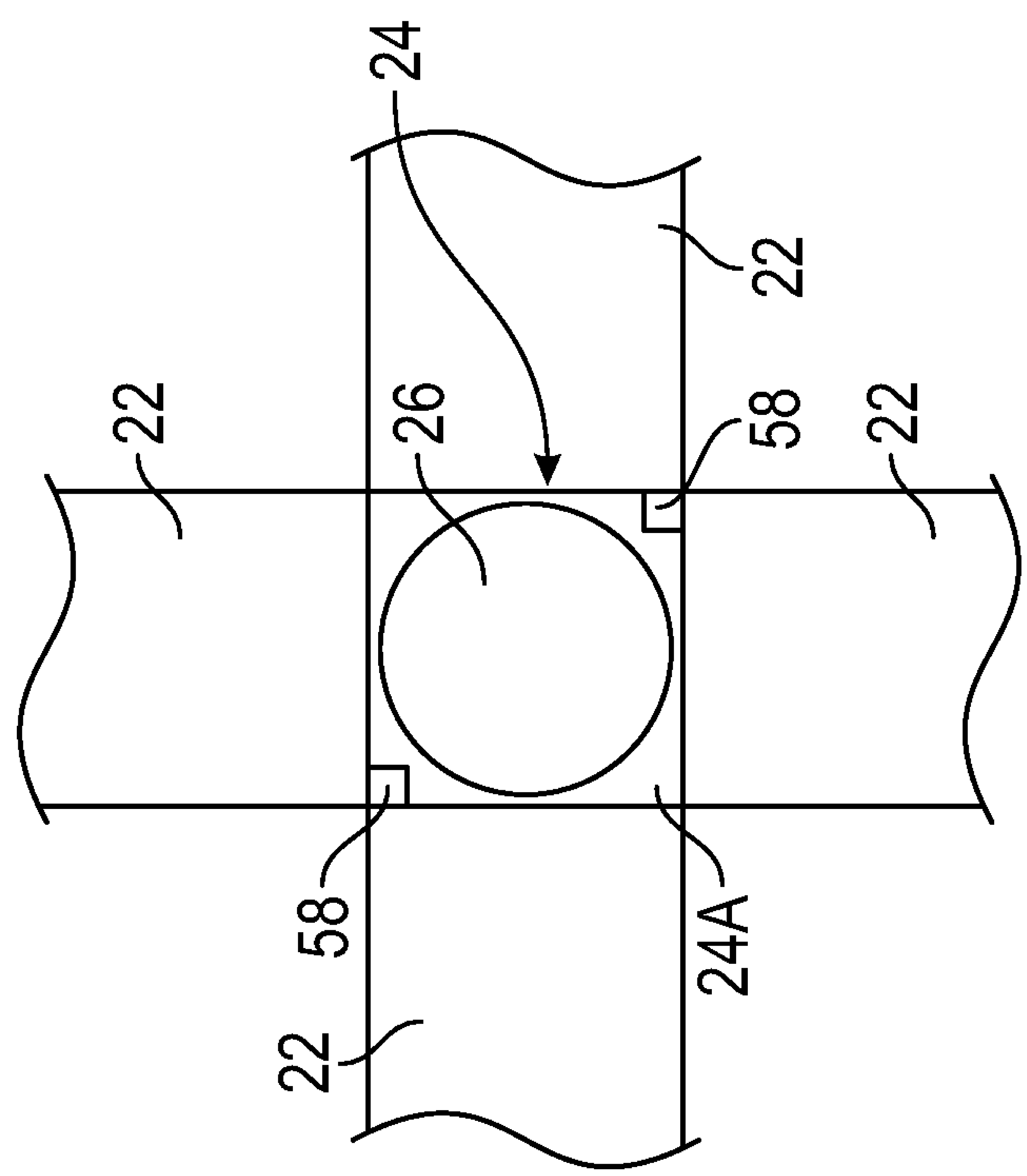

FIG. 5

METHOD OF ASSEMBLING AND DEPLOYING A FLOATING OFFSHORE WIND TURBINE PLATFORM

BACKGROUND OF THE INVENTION

[0001] This invention relates in general to wind turbine platforms. In particular, this invention relates to an improved method of assembling and deploying a floating offshore wind turbine (FOWT) platform into a body of water.

[0002] Wind turbines for converting wind energy to electrical power are known and provide an alternative energy source for power companies. On land, large groups of wind turbines, often numbering in the hundreds of wind turbines, may be placed together in one geographic area. These large groups of wind turbines can generate undesirably high levels of noise and may be viewed as aesthetically unpleasing. An optimum flow of air may not be available to these land-base wind turbines due to obstacles such as hills, woods, and buildings.

[0003] Groups of wind turbines may also be located offshore, but near the coast at locations where water depths allow the wind turbines to be fixedly attached to a foundation on the seabed. Over the ocean, the flow of air to the wind turbines is not likely to be disturbed by the presence of various obstacles (i.e., as hills, woods, and buildings) resulting in higher mean wind speeds and more power. The foundations required to attach wind turbines to the seabed at these near-coast locations are relatively expensive, and can only be accomplished at relatively shallow depths, such as a depth of up to about 45 meters.

[0004] The U.S. National Renewable Energy Laboratory has determined that winds off the U.S. Coastline over water having depths of 30 meters or greater have an energy capacity of about 3,200 TWh/yr. This is equivalent to about 90 percent of the total U.S. energy use of about 3,500 TWh/yr. The majority of the offshore wind resource resides between 37 and 93 kilometers offshore where the water is over 60 meters deep. Fixed foundations for wind turbines in such deep water are likely not economically feasible. This limitation has led to the development of floating platforms for wind turbines. Known floating wind turbine platforms are formed steel and are based on technology developed by the offshore oil and gas industry. There remains a need in the art however, for improved methods of assembling and deploying a FOWT platform.

SUMMARY OF THE INVENTION

[0005] This invention relates in general to methods of assembling and deploying a floating offshore wind turbine (FOWT) platforms and the wind turbines mounted thereon. The FOWT platforms described herein are characterized by a negatively buoyant mass suspended from a positively buoyant floater by a plurality of suspension lines. In particular, this invention relates to an improved method of assembling and deploying a floating offshore wind turbine (FOWT) platform including floating a hollow outer tank in a floating assembly area of a body of water, the hollow outer tank having transit lines and suspension lines attached thereto, floating a buoyant floater in the floating assembly area of the body of water, and placing permanent ballast material in the outer tank to define a mass, and sinking the mass to a seabed of the body of water. Free ends of the transit lines and the suspension lines are raised to a surface of the body of water with buoys, and the buoyant floater is moved to a position over the mass. The transit lines are attached to a lifting device in the buoyant floater and the suspension lines are attached to a portion of the buoyant floater, the combined buoyant floater and the mass defining a FOWT platform. The mass is lifted with the lifting device to a point directly under the buoyant floater, and the FOWT platform is towed to an installation site in the body of water. Mooring lines are attached to anchors in the seabed and to the buoyant floater. The mass is lowered with the transit lines and the lifting device to a depth wherein the suspension lines are taught, thus suspending the mass with the suspension lines to define a suspended mass. The transit lines are then stored or removed from the mass.

[0006] Various aspects of this invention will become apparent to those skilled in the art from the following detailed description of the preferred embodiment, when read in light of the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** is a perspective view of a floating offshore wind turbine platform assembled and deployed according to the improved method of this invention.

[0008] FIG. **2** is an alternate perspective view of the FOWT platform illustrated in FIG. **1** showing the suspended mass and the suspension lines connecting the suspended mass to the buoyant floater.

[0009] FIG. **3** is a cross-sectional view of the suspended mass illustrated in FIGS. **1** and **2**.

[0010] FIG. **4**A is a schematic illustration of a first step of a first embodiment of the improved method of this invention.

[0011] FIG. **4**B is a schematic illustration of a second step of the first embodiment of the improved method of this invention.

[0012] FIG. **4**C is a schematic illustration of a third step of the first embodiment of the improved method of this invention.

[0013] FIG. **4**D is a schematic illustration of a fourth step of the first embodiment of the improved method of this invention.

[0014] FIG. **4**E is a schematic illustration of a fifth step of the first embodiment of the improved method of this invention.

[0015] FIG. **4**F is a schematic illustration of a sixth step of the first embodiment of the improved method of this invention.

[0016] FIG. **5** is a top plan view of a portion of the buoyant floater illustrated in FIGS. **1** through **3**.

[0017] FIG. **6** is a perspective view of an alternate embodiment of the suspended mass illustrated in FIGS. **1** through **3**.

[0018] FIG. **7** is a perspective view of the buoyant floater sub-assembly.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0019] The present invention will now be described with occasional reference to the specific embodiments of the invention. This invention may, however, be embodied in different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

[0020] Referring to the drawings, particularly to FIGS. **1** and **2**, an embodiment of a floating offshore wind turbine (FOWT) foundation or platform is shown at **10**. The illustrated FOWT platform **10** is shown anchored to a bed of a body of water BW. The FOWT platform **10** is representative of a FOWT platform that has been assembled and deployed in accordance with the improved method of this invention. In the illustrated embodiment, the FOWT platform **10** is shown anchored to the seabed S. It will be understood that the seabed S may be the bed of any body of water in which the FOWT platform **10** will be placed into operation.

[0021] The illustrated FOWT platform **10** includes a buoyant floater **12** and a negatively buoyant mass **36** suspended from the buoyant floater **12**. The buoyant floater **12** supports a tower **14**, described below in detail. The tower **14** supports a wind turbine **16**. The FOWT platform **10** is structured and configured to float, partially submerged, in a body of water. Accordingly, a portion of the buoyant floater **12** will be above water when the buoyant floater **12** is floating in the water and deployed at an operational draft, described below. As best shown in FIG. **1**, a portion of the buoyant floater **12** is also below the waterline, as illustrated by the line WL on a central column **26**, described below. As used herein, the waterline WL is defined as the approximate line where the surface of the water meets the FOWT platform **10**. One or more mooring lines **18**, two of which are shown in FIG. **1**, may be attached to the FOWT platform **10** and further attached to anchors, such as the anchors **20** in the seabed S to limit to movement of the FOWT platform **10** on the body of water BW.

[0022] The illustrated buoyant floater **12** is formed from four pontoons **22** that extend radially outwardly from a central hub **24** and provide buoyancy. It will be understood that the buoyant floater **12** is configured to provide the primary source of buoyancy for the FOWT platform **10**. When assembled together, the pontoons **22** and the central hub **24** define a generally cross-shaped base **25**. The central column **26** is mounted to the central hub **24** and extends outwardly (upwardly when viewing FIGS. **1** and **2**) and perpendicularly to the pontoons **22**, and also provides buoyancy. Additionally, the central column **26** supports the tower **14**, which is attached thereto. Optionally, braces **28** may connect distal ends of the pontoons **22** to an upper portion of the central column **26**. Each pontoon **22** may be attached to one of the anchors **20** with one of the mooring lines **18**.

[0023] The illustrated pontoons **22** have a rectangular cross-sectional shape. Alternatively, the pontoons **22** may have other shapes, such as, but not limited to, cylindrical, conical, and tubular having other desired geometric cross-sectional shapes such as pentagonal and hexagonal.

[0024] If desired, a catwalk or access platform (not shown) may be attached to the upper portion of the central column **26**. Additionally, one or more access ladders (not shown) may mounted internally or externally of the central column **26**.

[0025] In the embodiments illustrated herein, the wind turbine **16** is a horizontal-axis wind turbine. The size of the wind turbine **16** will vary based on the wind conditions at the location where the FOWT platform **10** is anchored and the desired power output. Advantageously, it has been shown that the illustrated FOWT platform **10** is ideally suited to support conventional commercial offshore wind turbines **16** having an output in the range of about 6 MW to about 20 MW. Alternatively, the FOWT platform **10** may be configured to support wind turbines **16** may having an output less than about 6 MW and greater than about 20 MW.

[0026] The wind turbine **16** includes a rotatable hub **30**. At least one rotor blade **32** is coupled to and extends outward from the hub **30**. The hub **30** is rotatably coupled to an electric generator (not shown). The electric generator may be coupled via a transformer (not shown) and an underwater power cable (not shown), as shown in FIG. **1**, to a power grid (not shown). In the illustrated embodiment, the rotor has three rotor blades **32**. In other embodiments, the rotor may have more or less than three rotor blades **32**. A nacelle **34** is attached to the wind turbine **16** opposite the hub **30**. In the embodiments illustrated herein, the wind turbine **16** is a horizontal-axis wind turbine (HAWT). Alternatively, the FOWT platform **10** may be configured to have a vertical-axis wind turbine (VAWT) mounted thereon.

[0027] Referring again to FIG. **1**, the negatively buoyant mass **36** is shown suspended from the buoyant floater **12** by a plurality of suspension lines **38**. Advantageously, the mass **36** has a simple design including a housing or outer tank **40** having cylindrical wall **42** enclosed by a first axial end wall **44** (the upper wall when viewing FIGS. **1** through **3**) and a second axial end wall **46** (the lower wall when viewing FIGS. **1** through **3**). The illustrated outer tank **40** is preferably formed from reinforced concrete and has a diameter of 15.15 m and a height of 11.94 m. An interior of the outer tank **40** includes a permanent ballast space configured to hold permanent ballast material **48** in a lower portion thereof, and a variable ballast space **50** in an upper portion thereof. As best shown in FIG. **2**, four fairleads **52** are mounted to the first end wall **44**. Alternatively, the outer tank **40** may have more than four fairleads **52**, may have three fairleads **52**, or may have two fairleads **52**. Additionally, the first end wall **44** may have only one, centrally mounted fairlead **52**, as shown in FIG. **6**. The illustrated mass **36** has a cylindrical shape. Alternatively, the mass **36** may have other shapes, such as spherical, and cylindrical having a semi-spherical lower portion.

[0028] The permanent ballast material **48** may be any desired material, such as iron ore, or other material selected to achieve a desired, pre-determined mass necessary to balance gravity and the buoyancy of the assembled FOWT platform **10** as a complete system.

[0029] The plurality of suspension lines **38** that attach the mass **36** to the buoyant floater **12** may be formed from synthetic ropes, chains, cables, such as steel cables, and tubular steel structures. As shown in FIG. **2** the mass **36** is attached to each pontoon **22** by two suspension lines **38**, for a total of eight suspension lines **38**. The mass **36** may also be attached to each pontoon by a single suspension line **38** or by more than two suspension lines **38**. When the FOWT platform **10** is fully deployed in a body of water BW, as described in detail below, each suspension line **38** will have a length sufficient so that the mass **36** will be suspended about 75.10 m below the buoyant floater **12**. The mass **36** may include a pump (not shown) for removing sea water from the variable ballast space **50**.

[0030] The distance that the mass **36** may be suspended below the buoyant floater **12** will vary based on the size of the buoyant floater **12** and the size of the wind turbine **16** and the tower **14** supported thereon. For example, in an alternate embodiment of the FOWT platform **10**, the mass **36** may be suspended about 40 m below a lower surface of the buoyant floater **12**.

[0031] The illustrated central hub **24** is hollow and has four side walls, each side wall having a width of about 10.98 m and an axial length or height of about 8.53 m. Each side wall of the central hub **24** defines a substantially vertical connection face to which the pontoons **22** will be attached. In the illustrated embodiment, the central hub **24** includes four side walls and has a substantially square cross-sectional shape. The four side walls are enclosed by a first axial end wall **24**A (the upper wall when viewing FIGS. **1** and **2**) and a second axial end wall (the lower wall when viewing FIGS. **1** and **2**). Alternatively, the central hub **24** may have other configurations, such as three side walls for the attachment of three pontoons **22**. The central hub **24** may also have internal watertight bulkheads for strength and/or to define variable water ballast chambers (not shown).

[0032] The illustrated central hub **24** may be formed from pre-stressed reinforced concrete, and may include an internal central cavity (not shown). Any desired process may be used to manufacture the central hub **24**, such as a spun concrete process, with conventional concrete forms, or with reusable concrete forms in a semi-automated process such as used in the precast concrete industry. The concrete of the central hub **24** may be reinforced with any conventional reinforcement material, such as high tensile steel cable and high tensile steel reinforcement bars or REBAR. Alternatively, the central hub **24** may be formed from FRP, steel, or combinations of pre-stressed reinforced concrete, FRP, and steel. The central hub **24** may be formed in sections, as described below.

[0033] Each pontoon **22** is also hollow and has a width of 10.98 m, a height of 8.53 m, and a length of 27.08 m. Like the central hub **24**, the illustrated pontoons **22** are formed from pre-stressed reinforced concrete as described above. Alternatively, the pontoons **22** may be formed from FRP, steel, or combinations of pre-stressed reinforced concrete, FRP, and steel. The pontoons **22** may be formed in sections, as described below.

[0034] The central column **26** is hollow and has a diameter of 10.44 m and a height of 26.5 m. The central column **26** includes a cylindrical side wall **27** having an outer surface, a first axial end wall **26**A (the upper wall when viewing FIGS. **1** and **2**), a second axial end wall **26**B (the lower wall when viewing FIGS. **1** and **2**), and defines a hollow interior space (not shown). The hollow central column **26** may include transverse bulkheads or decks configured and positioned for strength or for the mounting of electrical and mechanical components of the FOWT platform **10**.

[0035] Like the central hub **24** and the pontoons **22**, the illustrated central column **26** is formed from pre-stressed reinforced concrete as described above. Alternatively, the central column **26** may be formed from FRP, steel, or combinations of pre-stressed reinforced concrete, FRP, and steel. The central column **26** may be formed in sections, as described below. The illustrated braces **28** are formed from steel.

[0036] The pontoons **22** provide a source of buoyancy and define a water-plane area when the buoyant floater **12** is being towed in a body of water BW. Although not illustrated, each pontoon **22** may include watertight transverse bulkheads for watertight stability, and longitudinally extending bulkheads, and decks, arranged perpendicularly to side walls of the pontoon **22** for strength. Additionally, the internal bulkheads in each pontoon **22** may define ballast chambers (not shown) for variable water ballast.

[0037] The illustrated FOWT platform **10** includes four pontoons **22**. It will be understood however, that the FOWT platform **10** assembled in accordance with the improved method of this invention, may be constructed with three pontoons **22** or with more than four pontoons **22**.

[0038] Advantageously, temporary transit lines **56** and a lifting devices such as winches or chain jacks, schematically illustrated at **58**, movably connect the mass **36** to the buoyant floater **12** during deployment and re-deployment, as described below. The transit lines **56** may be lengths of chain or cables, such as steel cables. As best shown in FIGS. **4**E and **5**, the transit lines **56** connect the mass **36** to the buoyant floater **12** via the winches or chain jacks **58**. The chain jacks **58** may be mounted at any desired location on or within the buoyant floater **12**, such as on the first axial end wall **24**A of the central hub **24**, as shown in FIG. **5**. Alternatively, the chain jacks **58** may be mounted within the central hub **24**, or on or within one or more of the pontoons **22**.

[0039] As described above each of the components of the mass **36** and the buoyant floater **12**, i.e., the central hub **24**, the pontoons **22**, and the central column **26** may be formed from concrete and may have cross-sectional shapes other than as illustrated.

[0040] The mass **36** and the buoyant floater **12**, including the individual components of the buoyant floater **12**, may be formed in different sizes to be determined by the size of the wind turbine **16** and the tower **14** supported thereon.

[0041] In a first embodiment of a method of forming the mass **36** and the buoyant floater **12**, the outer tank **40** may be formed, i.e., pre-cast, as one large, monolithic section, or may be formed in two or more sections (not shown). Such sections may then be post-tensioned together during assembly of the outer tank **40**. Similarly, the central hub **24** may be formed as one large, monolithic section, or may be formed in two or more sections (not shown), although preferably not more than four sections. Such sections may then be transversely post-tensioned together (i.e., transversely to its axial length) during assembly of the central hub **24**.

[0042] The pontoons **22** may be formed in sections, such as sections having a length of about 3 meters. Thus, in one exemplary embodiment, each pontoon **22** may be formed in nine sections. As will be described below, the pontoons **22** may be longitudinally post-tensioned in pairs after each of the pair of pontoons **22** has been assembled to the central hub **24**.

[0043] The central column **26** may likewise be formed in sections, such as sections having a length of about 3 meters. Thus, in one exemplary embodiment, the central column **26** may be formed in about nine sections. As will be described below, the central column **26** may be longitudinally post-tensioned.

[0044] A first embodiment of a method of assembling and deploying the buoyant floater **12** includes forming and assembling a plurality of the pontoons **22**, the central hub **24**, the central column **26**, the mass **36**, and the braces **28** by any of the methods described herein in an on-shore location. Two of the pontoons **22** may then be assembled to the central hub **24** and the assembled pontoons **22** and central hub **24** may be post-tensioned from a distal end of one of the pontoons **22** to a distal end of the other of the pontoons **22**.

A third pontoon **22** and a fourth pontoon **22** may then be assembled to the central hub **24** and may also be post-tensioned from a distal end of the third pontoon **22** to a distal end of the fourth pontoon **22**.

[0045] The central column **26** may then be assembled from sections on the first axial end wall **24**A of the central hub **24** and longitudinally post-tensioned. The braces **28**, if provided, may then be attached between the pontoons **22** and the central column **26**. The tower **14** and the wind turbine **16** may then be installed, thus defining the buoyant floater **12**. The buoyant floater **12** may be launched into the body of water BW by any conventional method, such as by using finger piers (not shown).

[0046] For example, a pair of finger piers (not shown) may extend outwardly from the shoreline SL or a dock (not shown). The buoyant floater **12** may be moved, such as by rail or other desired means of transport, onto the finger piers such that a portion of the buoyant floater **12** is supported on distal ends of both of the finger piers and supported thereon above a surface of the body water BW, and a portion of the buoyant floater **12** remains supported on the shore line or dock from which the finger piers extend. A floating launch platform, such as a semi-submersible or launch barge (not shown) may be moved between the finger piers and underneath the buoyant floater **12**. Once positioned beneath the buoyant floater **12**, ballast may be removed from the launch platform to cause the launch platform to rise in the body of water BW until the launch platform lifts the buoyant floater **12** off of the finger piers and the shoreline, thereby transferring the buoyant floater **12** onto the launch platform. The launch platform may then be towed to a launch area in the body of water BW.

[0047] Although the first embodiment of the method assembling and deploying the buoyant floater **12** is described as occurring in an on-shore location, it will be understood that the buoyant floater **12** may also be assembled in a dry dock, if the dry dock is large enough accommodate assembled buoyant floater or any of its component part or subassemblies, such as an assembled assembly of two pontoons **22** and the central hub **24**.

[0048] A second embodiment of the method of assembling and deploying the buoyant floater **12** occurs within a dry dock (not shown) and includes forming and assembling two of the pontoons **22**, assembling the central hub **24**, assembling the pontoons **22** to the central hub **24**, and post-tensioned the assembled pontoons **22** and central hub **24** from a distal end of one of the pontoons **22** to a distal end of the other of the pontoons **22** to define a buoyant floater sub-assembly **60** that is fully capable of floating on its own.

[0049] Once assembled, the buoyant floater sub-assembly **60** may be launched from the dry dock in a conventional manner and allowed to float in a floating assembly area (not shown), preferably near the dry dock.

[0050] Two additional pontoons **22** may then be assembled in the dry dock, and temporarily post-tensioned to provide structural integrity of the pontoons **22** prior to being assembled onto the buoyant floater sub-assembly **60**. Once assembled, the two additional pontoons **22** may be launched from the dry dock in a conventional manner and allowed to float in the floating assembly area (not shown) wherein the buoyant floater sub-assembly **60** is located.

[0051] Each of the two additional pontoons **22** are then mated to the open side walls of the central hub **24** of the buoyant floater sub-assembly **60** and attached thereto. The two additional pontoons **22** and the central hub **24** are then post-tensioned from a distal end of one of the pontoons **22** to a distal end of the other of the pontoons **22** to define the buoyant floater **12**.

[0052] It will be understood that when floating, a portion of the buoyant floater sub-assembly **60** and a portion of the buoyant floater **12** remain above the water line, as shown in FIG. **7**. It will be further understood that the step of post-tensioning the buoyant floater sub-assembly **60** and the additional pontoons **22** to the buoyant floater sub-assembly **60** to define the buoyant floater **12** will occur above the waterline, and will therefore be in dry portions of the pontoons **22** and the central hub **24**.

[0053] The central column **26** may then be formed in sections on shore, such as described above, assembled on the first axial end wall **24**A of the central hub **24** while the buoyant floater **12** is floating, such as alongside a dock, and longitudinally post-tensioned. The braces **28** may then be attached between the pontoons **22** and the central column **26**, also while the buoyant floater **12** is floating alongside a dock.

[0054] The tower **14** and the wind turbine **16** may then be installed on the central column **26** while the buoyant floater **12** is floating, preferably above the submerged mass **36**, as described below. Alternatively, if the depth of the body of water BW permits it, ballast may be added to the buoyant floater **12** to move the buoyant floater **12** temporarily to the seabed S to install the tower **14** and the wind turbine **16**.

[0055] The depth of the mass **36** is variable, thus allowing for a shallow tow-out draft of about 10 m or less, that is comparable to a semi-submersible FOWT. Thus, the FOWT platform **10** has the mobility characteristics of a semi-submersible FOWT combined with the stability characteristics of a spar-type platform.

[0056] As configured in the embodiments described herein, the buoyant floater **12** has a tow-out or shallow draft of 7.53 m and the assembled FOWT platform **10** has an operational draft of 21.25 m.

[0057] A first embodiment of a method of assembling and deploying the mass **36** includes forming, such as by casting, sections (not shown) of the outer tank **40** in an on-shore location. Such sections may then be post-tensioned together. The assembled, but empty outer tank **40** may then be launched into the body of water BW by any desired method and allowed to float in the floating assembly area (not shown) wherein the buoyant floater **12** is located.

[0058] A second embodiment of a method of assembling and deploying the mass **36** includes forming the outer tank **40** as one large, monolithic section using conventional slip-forming or staged casting methods in an on-shore location. Once cast, the empty outer tank **40** may then be launched into the body of water BW by any desired method and allowed to float in the floating assembly area (not shown) wherein the buoyant floater **12** is located.

[0059] A first embodiment of the improved method of assembling and deploying the FOWT platform **10** into a body of water BW is shown schematically in FIGS. **4**A through **4**F.

[0060] As shown in FIG. **4**A, an empty outer tank **40** of the mass **36** may be launched from a dock or shoreline SL into the body of water BW by any desired method and allowed to float in the floating assembly area (not shown) wherein the buoyant floater **12** is located (the buoyant floater **12** is not shown in FIGS. **4**A or **4**B, but is shown in FIGS. **4**C through **4**F).

[0061] The permanent ballast material **48** may then be added to the outer tank **40**, thus defining the mass **36**, and causing the mass **36** to sink to the seabed S, as shown in FIG. **4**B. As the mass **36** sinks, the variable ballast space **50** fills with sea water.

[0062] The transit lines **56** and the suspension lines **38** may be preinstalled on the mass **36** and may be carried to the surface of the body of water BW with marker buoys attached to free ends of each of the transit lines **56** and the suspension lines **38**.

[0063] If not already launched into the body of water BW, the buoyant floater **12** may be launched and then floated, i.e., moved, to a position over the mass **36**. At this step of the method of assembling and deploying the FOWT platform **10** into a body of water BW, the ballast chambers in the buoyant floater **12** contain no ballast water, thus allowing the buoyant floater **12** to float. It is at this step also, that the tower **14** and the wind turbine **16** may then be installed on the central column **26** while the buoyant floater **12** is floating.

[0064] The temporary transit lines **56** and associated chain jacks **58** may now be used to lift the mass **36** to a point directly under the buoyant floater **12** to define a shallow draft configuration, i.e., the draft of 7.53 m, as shown in FIGS. **4**C and **4**D. The installed suspension lines **38** are attached to the mass **36** and left slack. At this point, the FOWT platform **10** behaves as a rigid body characterized by a vertical center of gravity that is above the vertical center of buoyancy. Thus, FOWT platform **10** stability is achieved via a waterplane moment of inertia generated by the partially submerged pontoons **22** of the FOWT platform **10**.

[0065] The now assembled FOWT platform **10** may then be towed to an installation site in the body of water BW. At this point, the FOWT platform **10** continues to behave as a rigid body characterized by a vertical center of gravity that is above the vertical center of buoyancy. Thus, the FOWT platform's **10** natural periods may fall within a range of typical wave periods. Accordingly, this step of towing the assembled FOWT platform to the installation site in the body of water BW should only be conducted in relatively calm seas.

[0066] Alternatively, means other than the winches or chain jacks **58** may be used to raise and lower the mass **36** to and from the buoyant floater **12**. Alternative means for raising and lowering the mass **36** include, but are not limited to, a removable floatation device, such as an inflatable device, removable, external ballast tanks, and temporary barge support. Additionally, the mass **36** may be configured to float under or alongside the buoyant floater **12**.

[0067] Once the FOWT platform **10** has reached the installation site in the body of water BW, the mooring lines **18** attached to the pontoons **22** of the FOWT platform **10** may be connected to the anchors **20** in the seabed S. The mass **36** may then be lowered using the temporary transit lines **56** and associated chain jacks **58**, as shown in FIG. **4**E. The temporary transit lines **56** may be removed from the mass **36** once the suspension lines **38** become taught, and thus carry the full weight of the suspended mass **36**, as shown in FIG. **4**F.

[0068] The pontoons **22** may be fully submerged by flooding the internal ballast chambers with sea water. The FOWT platform **10** now rests at its design draft, as shown in FIG. **4**E, and wherein the FOWT platform **10** is positioned in the body of water BW such that the waterline WL is at a mid-point of the central column **26**.

[0069] Although FIGS. **1** through **4**F illustrate the mass **36** having four fairleads **52** for the connection of suspension lines **38**, the mass **36** may include any desired number of fairleads **52**, configured for the attachment of any desired number of suspension lines **38**. For example, the mass **36** may include three fairleads **52**, two fairleads **52**, or a single fairlead **52**, as shown in FIG. **6**, wherein an alternate embodiment of the mass **66** has only one fairlead **52** mounted to a first end wall **68** thereof.

[0070] Advantageously, by allowing the suspended mass **36** to be free to rotate and have its own natural period of vibration, it may be tuned to mitigate the motion experienced by the deployed buoyant floater **12**. This period of vibration may be obtained by precisely selecting the number of suspension lines **38**, their attachment point or points on the mass **36**, and tuning the center of gravity location and mass moment of inertia of the suspended mass **36**, to achieve a vibrational frequency that is favorable for reducing motion of the buoyant floater **12** and wind turbine nacelle **34**.

[0071] The principle and mode of operation of this invention have been explained and illustrated in its preferred embodiment. However, it must be understood that this invention may be practiced otherwise than as specifically explained and illustrated without departing from its spirit or scope.

What is claimed is:

1. A method of assembling and deploying a floating offshore wind turbine (FOWT) platform comprising:

floating a hollow outer tank in a floating assembly area of a body of water, the hollow outer tank having transit lines and suspension lines attached thereto;

floating a buoyant floater in the floating assembly area of the body of water;

placing permanent ballast material in the outer tank to define a mass, and sinking the mass to a seabed of the body of water;

raising free ends of the transit lines and the suspension lines to a surface of the body of water with buoys;

moving the buoyant floater to a position over the mass;

attaching the transit lines to a lifting device in the buoyant floater and attaching the suspension lines to a portion of the buoyant floater, the combined buoyant floater and the mass defining a FOWT platform;

lifting the mass with the lifting device to a point directly under the buoyant floater;

towing the FOWT platform an installation site in the body of water;

attaching mooring lines to anchors in the seabed and to the buoyant floater;

lowering the mass with the transit lines and the lifting device to a depth wherein the suspension lines are taught, thus suspending the mass with the suspension lines to define a suspended mass; and

one of storing and removing the transit lines from the mass.

2. The method of assembling and deploying a FOWT platform according to claim **1**, wherein the hollow outer tank and the buoyant floater are launched from one of a dock and shoreline into the body of water.

3. The method of assembling and deploying a FOWT platform according to claim **1**, wherein the permanent ballast material is iron ore.

4. The method of assembling and deploying a FOWT platform according to claim **1**, wherein the hollow outer tank defines a permanent ballast space and a variable ballast space, and wherein as the mass sinks, the variable ballast space fills with sea water

5. The method of assembling and deploying a FOWT platform according to claim **1**, wherein the step of lifting the mass with the lifting device to a point directly under the buoyant floater includes attaching marker buoys to free ends of each of the transit lines and the suspension lines.

6. The method of assembling and deploying a FOWT platform according to claim **1**, further including installing a tower and a wind turbine on the buoyant floater prior to the step of lifting the mass with the lifting device to a point directly under the buoyant floater.

7. The method of assembling and deploying a FOWT platform according to claim **1**, wherein when the mass has been lifted and positioned directly under the buoyant floater, the FOWT platform is in a shallow draft configuration.

8. The method of assembling and deploying a FOWT platform according to claim **1**, wherein in the shallow draft configuration, the suspension lines are slack.

9. The method of assembling and deploying a FOWT platform according to claim **8**, wherein in the shallow draft configuration, the FOWT platform behaves as a rigid body having by a vertical center of gravity that is above its vertical center of buoyancy.

10. The method of assembling and deploying a FOWT platform according to claim **1**, wherein a first end wall of the outer tank of the mass includes a fairlead for attaching at least one of the suspension lines.

11. The method of assembling and deploying a FOWT platform according to claim **1**, wherein a first end wall of the outer tank of the mass includes a plurality of fairleads, each configured for attaching at least one of the suspension lines.

12. The method of assembling and deploying a FOWT platform according to claim **1**, wherein the buoyant floater includes:

a central hub;

three or more buoyant pontoons that extend radially outwardly from the central hub, and defining cross-shaped base;

a central column mounted to the central hub and extending outwardly and perpendicularly to the pontoons; and

braces connecting distal ends of the pontoons to an upper portion of the central column.

13. The method of assembling and deploying a FOWT platform according to claim **11**, further including a tower supporting a wind turbine on the central column.

14. The method of assembling and deploying a FOWT platform according to claim **12**, wherein at least one of the outer tank, the central hub, the buoyant pontoons, and the central column are formed in sections.

15. The method of assembling and deploying a FOWT platform according to claim **12**, further including:

forming and assembling a plurality of the pontoons, the central hub, the mass, and the braces in an on-shore location;

assembling a first and a second pontoon to the central hub;

post-tensioning the assembled first and second pontoons and central hub from a distal end of the first pontoon to a distal end of the second pontoon to define a buoyant floater sub-assembly;

assembling a third and a fourth pontoon to the hub of the buoyant floater sub-assembly; and

post-tensioning the assembled third and fourth pontoons and buoyant floater sub-assembly from a distal end of the third pontoon to a distal end of the fourth pontoon.

16. The method of assembling and deploying a FOWT platform according to claim **15**, further including:

forming sections of the central column;

assembling the sections of the central column on a first axial end wall of the central hub;

longitudinally post-tensioning the central column to the hub;

attaching the braces between the pontoons and the central column;

installing the tower and the wind turbine, thus defining the buoyant floater; and

launching the buoyant floater into the body of water.

17. The method of assembling and deploying a FOWT platform according to claim **12**, further including:

forming and assembling a first and a second pontoon within a dry dock;

assembling the central hub within the dry dock;

assembling the first and second pontoons to the central hub;

post-tensioning the assembled first and second pontoons and central hub from a distal end of the first pontoon to a distal end of the second pontoon to define a buoyant floater sub-assembly;

launching the buoyant floater sub-assembly into a floating assembly area;

forming and assembling a third and a fourth pontoon within the dry dock;

temporarily post-tensioning each of the third and the fourth pontoons;

launching the third and the fourth pontoons into the floating assembly area;

assembling a third and a fourth pontoon to the hub of the buoyant floater sub-assembly; and

post-tensioning the assembled third and fourth pontoons and buoyant floater sub-assembly from a distal end of the third pontoon to a distal end of the fourth pontoon, thus defining the buoyant floater.

18. The method of assembling and deploying a FOWT platform according to claim **12**, wherein the steps during the steps of post-tensioning the assembled first and second pontoons and central hub, and post-tensioning the assembled third and fourth pontoons and buoyant floater sub-assembly occur in portions of the first, second, third, and fourth pontoons and the central hub that are above a water line when the buoyant floater sub-assembly and the third and fourth pontoons are floating in the body of water.

19. The method of assembling and deploying a FOWT platform according to claim **1**, wherein the suspended mass has a natural period of motion that is selected based on the mass and a geometric location of attachment points of the suspension lines on the mass to reduce an overall motion of the FOWT platform.

20. The method of assembling and deploying a FOWT platform according to claim **1**, wherein the lifting device is one of a winch and a chain jack.

21. A method of assembling and deploying a floating offshore wind turbine (FOWT) platform comprising:

floating a hollow outer tank in a floating assembly area of a body of water, the hollow outer tank having transit lines and suspension lines attached thereto;

assembling a buoyant floater;

floating a buoyant floater in the floating assembly area of the body of water;

placing permanent ballast material in the outer tank to define a mass, and sinking the mass to a seabed of the body of water;

raising free ends of the transit lines and the suspension lines to a surface of the body of water with buoys;

moving the buoyant floater to a position over the mass;

attaching the transit lines to a lifting device in the buoyant floater and attaching the suspension lines to a portion of the buoyant floater, the combined buoyant floater and the mass defining a FOWT platform;

lifting the mass with the lifting device to a point directly under the buoyant floater;

towing the FOWT platform an installation site in the body of water;

attaching mooring lines to anchors in the seabed and to the buoyant floater;

lowering the mass with the transit lines and the lifting device to a depth wherein the suspension lines are taught, thus suspending the mass with the suspension lines to define a suspended mass; and

one of storing and removing the transit lines from the mass;

wherein the buoyant floater includes:

a central hub;

three or more buoyant pontoons that extend radially outwardly from the central hub, and defining cross-shaped base;

a central column mounted to the central hub and extending outwardly and perpendicularly to the pontoons;

braces connecting distal ends of the pontoons to an upper portion of the central column; and

a tower supporting a wind turbine on the central column; and

wherein the method further includes:

forming and assembling a plurality of the pontoons, the central hub, the mass, and the braces in an on-shore location;

assembling a first and a second pontoon to the central hub;

post-tensioning the assembled first and second pontoons and central hub from a distal end of the first pontoon to a distal end of the second pontoon to define a buoyant floater sub-assembly;

assembling a third and a fourth pontoon to the hub of the buoyant floater sub-assembly;

post-tensioning the assembled third and fourth pontoons and buoyant floater sub-assembly from a distal end of the third pontoon to a distal end of the fourth pontoon;

forming sections of the central column;

assembling the sections of the central column on a first axial end wall of the central hub;

longitudinally post-tensioning the central column to the hub;

attaching the braces between the pontoons and the central column;

installing the tower and the wind turbine, thus defining the buoyant floater; and

launching the buoyant floater into the body of water.

22. A method of assembling and deploying a floating offshore wind turbine (FOWT) platform comprising:

floating a hollow outer tank in a floating assembly area of a body of water, the hollow outer tank having transit lines and suspension lines attached thereto;

floating a buoyant floater in the floating assembly area of the body of water;

placing permanent ballast material in the outer tank to define a mass, and sinking the mass to a seabed of the body of water;

raising free ends of the transit lines and the suspension lines to a surface of the body of water with buoys;

moving the buoyant floater to a position over the mass;

attaching the transit lines to a lifting device in the buoyant floater and attaching the suspension lines to a portion of the buoyant floater, the combined buoyant floater and the mass defining a FOWT platform;

lifting the mass with the lifting device to a point directly under the buoyant floater;

towing the FOWT platform an installation site in the body of water;

attaching mooring lines to anchors in the seabed and to the buoyant floater;

lowering the mass with the transit lines and the lifting device to a depth wherein the suspension lines are taught, thus suspending the mass with the suspension lines to define a suspended mass; and

one of storing and removing the transit lines from the mass;

wherein the buoyant floater includes:

a central hub;

three or more buoyant pontoons that extend radially outwardly from the central hub, and defining cross-shaped base;

a central column mounted to the central hub and extending outwardly and perpendicularly to the pontoons; and

braces connecting distal ends of the pontoons to an upper portion of the central column; and

wherein the method further includes:

forming and assembling a first and a second pontoon within a dry dock;

assembling the central hub within the dry dock;

assembling the first and second pontoons to the central hub;

post-tensioning the assembled first and second pontoons and central hub from a distal end of the first pontoon to a distal end of the second pontoon to define a buoyant floater sub-assembly;

launching the buoyant floater sub-assembly into a floating assembly area;

forming and assembling a third and a fourth pontoon within the dry dock;

temporarily post-tensioning each of the third and the fourth pontoons;

launching the third and the fourth pontoons into the floating assembly area;

assembling a third and a fourth pontoon to the hub of the buoyant floater sub-assembly; and

post-tensioning the assembled third and fourth pontoons and buoyant floater sub-assembly from a distal end of the third pontoon to a distal end of the fourth pontoon, thus defining the buoyant floater.

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