(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
29 November 2012 (29.11.2012)

WIPO | PCT

(10) International Publication Number
WO 2012/162696 A2

(51) International Patent Classification:
G08C 17/02 (2006.01) *G08C 19/00* (2006.01)

(21) International Application Number:
PCT/US2012/039847

(22) International Filing Date:
29 May 2012 (29.05.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/490,386 26 May 2011 (26.05.2011) US

(71) Applicant *(for all designated States except US)*: **HORTON WISON DEEPWATER, INC.** [US/US]; 1400 Broadfield, Suite 500, Houston, Texas 77084 (US).

(72) Inventor; and

(75) Inventor/Applicant *(for US only)*: **HORTON, III, Edward E.** [US/US]; 6114 Crab Orchard, Houston, Texas 77057 (US).

(74) Agent: **FALESKI, Thaddeus J.**; Conley Rose, P.C., 1001 McKinney, Suite 1800, Houston, Texas 77002 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

(54) **Title**: OFFSHORE ANTENNA TOWER AND INSTRUMENT ARRAY WITH TENSION MEMBER

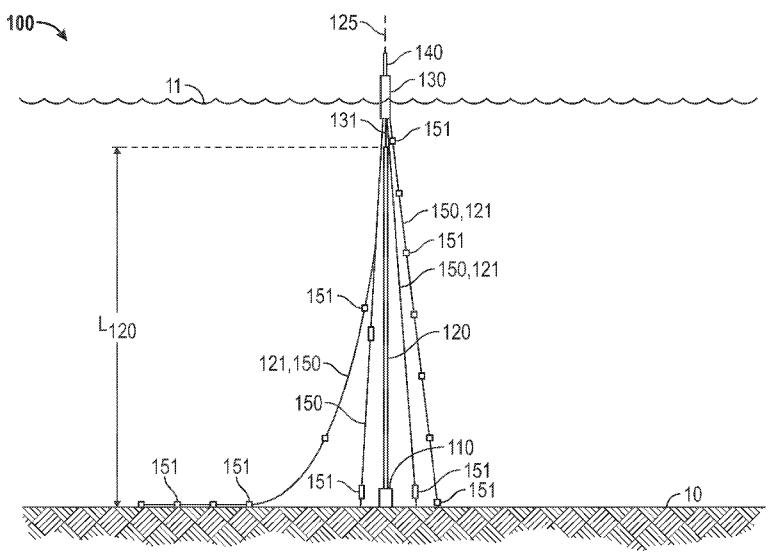


FIG. 1

(57) **Abstract**: A system for acquiring data in an offshore environment comprises an elongate composite tension member having a longitudinal axis, an upper end, and a lower end. In addition, the system comprises a buoyancy module coupled to the upper end of the composite tension member and configured to apply a tensile load to the tension member. Further, the system comprises a base coupled to the lower end of the composite tension member. The base is configured to secure the tension member to the sea floor. Still further, the system comprises a plurality of composite stringers coupled to the buoyant module and disposed about the tension member. Moreover, the system comprises a plurality of instrumentation systems configured to measure environmental or geological data. The instrumentation systems are coupled to the stringers.

WO 2012/162696 A2

OFFSHORE ANTENNA TOWER AND INSTRUMENT ARRAY WITH TENSION MEMBER

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0001] Not applicable.

BACKGROUND

Field of the Invention

[0002] The invention relates generally to an offshore system for gathering and communicating geological and environmental data across a range of depths. More specifically, the invention relates to a flexible composite tower supporting instrumentation to sense, gather, detect, store, and transmit geological and environmental data.

Background of the Technology

[0003] Data relating to the ocean environment such as the presence and movement of marine animals, water temperatures at varying depths, and currents at varying depths may be useful in studying and understanding global warming, its causes, and its effects over time. In addition, data relating to the geology and characteristics of subsea earthen formations (e.g., seismic data) may be useful in investigating and identifying scare natural resources such as oil and gas. However, a large majority of ocean bodies and large fresh water bodies, as well as the earth beneath such bodies, are generally under-investigated. Thus, very limited data relating to environmental conditions in such bodies and the geology beneath such bodies is available.

[0004] One conventional means to collect oceanic environmental data is with a surface vessel. However, such vessels collect data for a relatively short period of time at a given location, require an operator and personnel, and usually gather data relating to surface conditions (e.g., water temperature at the surface, wind speeds at the surface, presence of chemicals at the surface, etc.). Further, measurement of certain surface conditions with a vessel may be inaccurate as the vessel itself may alter the measured parameter. For example, the presence of a vessel may slightly alter the temperature of the water immediately surrounding it. Another conventional means to collect oceanic environmental data is with a weather buoy. Such buoys are typically moored (i.e., connected to the sea floor with a flexible chain or rope) or drifting (i.e., allowed to move along the ocean surface by wind and surface currents). However, weather buoys generally only collect data relating to surface conditions, and thus, provide little insight as to subsurface conditions, marine animals, and geology of formations below the

surface. In addition, drifting weather buoys do not gather data at a given location over a relatively long period of time as they are continuously moving.

[0005] Accordingly, there remains a need in the art for systems, devices, and methods for acquiring and communicating environmental and geological data in offshore locations. Such systems, devices, and methods would be particularly well-received if they could acquire and communicate environmental and geological data at a particular offshore location over a relatively long period of time.

BRIEF SUMMARY OF THE DISCLOSURE

[0006] These and other needs in the art are addressed in one embodiment by a system for acquiring data in an offshore environment. In an embodiment, the system comprises an elongate composite tension member having a longitudinal axis, an upper end, and a lower end. In addition, the system comprises a buoyancy module coupled to the upper end of the composite tension member and configured to apply a tensile load to the tension member. Further, the system comprises a base coupled to the lower end of the composite tension member. The base is configured to secure the tension member to the sea floor. Still further, the system comprises a plurality of composite stringers coupled to the buoyant module and disposed about the tension member. Moreover, the system comprises a plurality of instrumentation systems configured to measure environmental or geological data. The instrumentation systems are coupled to the stringers.

[0007] These and other needs in the art are addressed in another embodiment by a system for acquiring environmental and/or geological data in an offshore environment. In an embodiment, the system comprises an elongate tension member having a longitudinal axis, an upper end, and a lower end. The tension member comprises a plurality of parallel flexible composite tubular members. In addition, the system comprises an adjustably buoyant module coupled to the upper end of the tension member and configured to apply a tensile load to the tension member. Further, the system comprises a base coupled to the lower end of the composite tension member, the base configured to secure the tension member to the sea floor. Still further, the system comprises a plurality of stringers coupled to the adjustably buoyant module and configured to extend subsea. Moreover, the system comprises a plurality of instrumentation systems for measuring the environmental and/or geological data, wherein the instrumentation systems are coupled to the stringers.

[0008] These and other needs in the art are addressed in another embodiment by a method for acquiring environmental and/or geological data in an offshore environment. In an embodiment,

the method comprises (a) coupling a base to a first end of an elongate tension member. In addition, the method comprises (b) lowering the base to the sea floor with the tension member. Further, the method comprises (c) coupling a buoyancy module to a second end of the tension member. Still further, the method comprises (d) coupling a plurality of instrumentation systems to a plurality of stringers, wherein the instrumentation systems are configured to acquire subsea environmental data and/or geological data. Moreover, the method comprises (e) adjusting the buoyancy of the buoyancy module. The method also comprises (f) coupling the plurality of stringers to the buoyancy module, wherein each stringer has an upper end coupled to the buoyancy module and a lower end disposed subsea.

[0009] Embodiments described herein comprise a combination of features and advantages intended to address various shortcomings associated with certain prior devices, systems, and methods. The various characteristics described above, as well as other features, will be readily apparent to those skilled in the art upon reading the following detailed description, and by referring to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] For a detailed description of the preferred embodiments of the invention, reference will now be made to the accompanying drawings in which:

[0011] Figure 1 is a schematic view of an embodiment of an offshore instrumentation system for collecting and communicating environmental and subsea geological data in accordance with the principles described herein;

[0012] Figure 2 is a perspective view of the offshore instrumentation system of Figure 1;

[0013] Figure 3 is a cross-sectional view of the flexible tension member of Figure 1;

[0014] Figure 4 is a schematic cross-sectional view of the base of the instrumentation system of Figure 1;

[0015] Figure 5 is a schematic cross-sectional view of an embodiment of a base that may be used with the instrumentation system of Figure 1;

[0016] Figure 6 is a schematic cross-sectional view of the buoyancy module of the instrumentation system of Figure 1;

[0017] Figures 7A-7G are sequential views illustrating the deployment of the instrumentation system and installation of the base of Figure 1 from a surface vessel;

[0018] Figures 8A and 8B are sequential schematic cross-sectional views illustrating the installation of the base of Figure 5; and

[0019] Figure 9 is a side view of an embodiment of a device for facilitating the installation of the tension member of Figure 1 from the surface vessel of Figure 7A.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0020] The following discussion is directed to various exemplary embodiments. However, one skilled in the art will understand that the examples disclosed herein have broad application, and that the discussion of any embodiment is meant only to be exemplary of that embodiment, and not intended to suggest that the scope of the disclosure, including the claims, is limited to that embodiment.

[0021] Certain terms are used throughout the following description and claims to refer to particular features or components. As one skilled in the art will appreciate, different persons may refer to the same feature or component by different names. This document does not intend to distinguish between components or features that differ in name but not function. The drawing figures are not necessarily to scale. Certain features and components herein may be shown exaggerated in scale or in somewhat schematic form and some details of conventional elements may not be shown in interest of clarity and conciseness.

[0022] In the following discussion and in the claims, the terms "including" and "comprising" are used in an open-ended fashion, and thus should be interpreted to mean "including, but not limited to... ." Also, the term "couple" or "couples" is intended to mean either an indirect or direct connection. Thus, if a first device couples to a second device, that connection may be through a direct connection, or through an indirect connection via other devices, components, and connections. In addition, as used herein, the terms "axial" and "axially" generally mean along or parallel to a central axis (e.g., central axis of a body or a port), while the terms "radial" and "radially" generally mean perpendicular to the central axis. For instance, an axial distance refers to a distance measured along or parallel to the central axis, and a radial distance means a distance measured perpendicular to the central axis.

[0023] For purposes of discussion, composites, or composite materials, are materials consisting of more than one constituent material. Some composites are composed of at least two constituent materials, namely a matrix, which may be continuous and may surround a second phase termed a substrate (e.g., dispersed phase, reinforcing phase). The substrate being embedded in the matrix. The substrate (e.g., dispersed phase, reinforcing phase) may comprise any suitable material including without limitation, a metal or metal alloy (e.g., aluminum, titanium, stainless steel, etc.), a non-metal (e.g., fiberglass, carbon fiber, kevlar, quartz, polymer, ceramic, etc.) or combinations thereof. In addition, the substrate may comprise more

than one constituent material (e.g., a substrate may comprise both carbon fibers and glass fibers). Likewise, the matrix of a composite may comprise any suitable material including without limitation, a metal or metal alloy (e.g., aluminum, titanium, stainless steel, copper, etc.), a non-metal (e.g., resin, epoxy, polyester, polymer, ceramic, urethane, elastomer, etc.), or combinations thereof.

[0024] Referring now to Figures 1 and 2, an embodiment of an offshore system 100 for collecting and communicating environmental and subsea geological data is shown. System 100 is anchored to the sea floor 10 and extends vertically to the sea surface 11. In this embodiment, system 100 includes a base 110 disposed at the sea floor 10, an elongate tension member 120 extending upward from base 110, a buoyancy module 130 coupled to the upper end of tension member 120, and a communication antenna 140 extending upward from module 130 above the sea surface 11. A plurality of instrumentation stringers 150 are circumferentially disposed about tension member 120, each stringer 150 having an upper end coupled to buoyancy module 130 and a lower end disposed at the sea floor 10. As will be described in more detail below, each stringer 150 supports one or more instrumentation packages or systems 151 that measure and detect environmental and subsea geological data, and communicate the measured data to antenna 140, which then transmits the data via satellite or other means to any desired location for further processing, review, analysis, or combinations thereof.

[0025] Buoyancy module 130 is adjustably buoyant, places tension member 120 in tension and supports the weight of antenna 140, tension member 120, stringers 150, and systems 151 coupled to stringers 150. Base 110 secures tension member 120 to the sea floor 10 as the tensile load is applied to tension member 120 by module 130.

[0026] Referring now to Figures 1 and 3, tension member 120 is an elongate structure having a longitudinal axis 125, a length L_{120}, and a width or diameter W_{120}. Length L_{120} is significantly greater than width W_{120}. In particular, width W_{120} is preferably less than 12 inches, and more preferably less than 6 inches, and length L_{120} is preferably equal to or slightly less than the depth of water in which system 100 is disposed. In general, system 100 can be disposed in any depth of water, and thus, the length of tension member 120 can range anywhere from a few hundred feet to over 30,000 feet. Thus, for most offshore applications, tension member 120 has a length-to-width ratio greater than about 500 and less than 500,000.

[0027] In this embodiment, tension member 120 is formed from a plurality of flexible composite tubular members 121, each extending the entire length L_{120} of tension member 120. Tubular members 121 are arranged in a bundle held together by a plurality of axially

spaced annular bands 122. A flexible fluid conduit 123 is disposed in an interstitial space 124 between members 121. As will be described in more detail below, conduit 123 allows fluid communication between the surface 11 and base 110 during installation of system 100. It should also be appreciated that members 121 are also tubulars, and thus, could also be used to provide fluid communication between the surface 11 and base 110.

[0028] In general, each composite tubular member 121 may be made from any type of composite material capable of withstanding the anticipated loads applied thereto such as the tensile loads applied by buoyancy module 130 and wave/current loads, but is preferably made from pultruded fiberglass (i.e., fiberglass formed using a pultrusion manufacturing process). In addition, each composite tubular member 121 preferably has a width or diameter W_{121} less than 2.0 in., and more preferably about 1.0 in., a density of at least 95 lb/ft^3, and a tensile strength of at least 100,000 psi. Thus, composite tubular members 121 have a relatively high strength-to-weight ratio (i.e., higher than steel).

[0029] The relatively high strength-to-weight ratio of composite tubular members 121 allows tubular members 121 to have relatively small widths W_{121}, and hence allows tension member 120 to have a relatively small width W_{120}, while providing sufficient strength to resist the tensile loads applied by buoyancy module 130. This, in turn, reduces the weight of tubular members 121 and tension member 120, and hence, reduces the buoyancy demands placed on module 130. In addition, since composite tubular members 121 are relatively thin, lightweight, and flexible, tension member 120 and/or tubular members 121 can be carried on one or more spools of a single vessel, thereby simplifying storage and deployment of members 121 and tension member 120 in both shallow and deepwater applications.

[0030] As previously described and shown in Figure 3, tension member 120 comprises a bundle of composite tubular members 121. However, in other embodiments, the tension member (e.g., tension member 120) is made of a single composite tubular member (e.g., member 121).

[0031] Referring now to Figures 1 and 4, base 110 is coupled to the lower end of tension member 120 and secures system 100 to the sea floor 10. In this embodiment, the lower end of tension member 120 is directly attached to base 110, however, in other embodiments, the base (e.g., base 110) is coupled to the lower end of the tension member (e.g., tension member 120) by one or more intermediate connections. In general, base 110 may comprise any suitable device for anchoring tension member 120 to the sea floor 10 including a pile, a suction pile, a ballasted anchor, spud can, or the like. However, as best shown in Figure 4, in this embodiment, base 110 is a gravity anchor that relies on weight to embed and anchor

itself to the sea floor 10. In particular, base 110 comprises an enclosed vessel or housing 111 having a central axis 115 coaxially aligned with longitudinal axis 125, an upper end 111a attached to tension member 120, a lower end 111b configured to engage the sea floor 10, and an internal chamber or cavity 112. In addition, housing 111 includes a first through port 113 extending axially through upper end 111a and a second through port 114 proximal upper end 111a. In particular, housing 111 has a sidewall 116 extending axially between ends 111a, 111b, and second port 114 extends radially through sidewall 116 axially adjacent upper end 111a. First port 113 places inner chamber 112 in fluid communication with conduit 123 and second port 114 places chamber 112 in fluid communication with the surrounding environment. As will be described in more detail below, during deployment of system 100, base 110 is disposed subsea, and thus, water is free to flow into and out of chamber 112 through port 114. Further, base 110 is embedded and anchored to the sea floor 10 by pumping a heavy slurry (i.e., a slurry having a density greater than that of water) down conduit 123 and through port 113 into chamber 112, thereby displacing water from chamber 112 through port 114.

[0032] As previously described and shown in Figure 4, base 110 is a gravity anchor that relies on weight to embed and secure it to the sea floor. However, other types of bases may be used with system 100 instead of base 110. Referring now to Figure 5, another embodiment of a base 110' that may be used with system 100 in the place of base 110 is shown. In this embodiment, base 110' is a suction pile comprising an annular cylindrical skirt 111' having a central axis 115' coaxially aligned with axis 125, an upper end 111a' attached to the lower end of tension member 120, a lower end 111b', and a cylindrical inner chamber or cavity 112' extending axially between ends 111a', 111b'. Cavity 112' is closed off at upper end 111a', however, cavity 112' is completely open to the surrounding environment at lower end 111b'. A port 113' extending axially through upper end 111a' allows fluid communication between inner chamber 112' and conduit 123.

[0033] During installation of base 110', skirt 111' is urged axially downward into the sea floor 10. A suction/injection control system 170 is preferably used to facilitate the insertion and removal of base 110' into and from the sea floor 10. System 170 may be mounted to buoyancy module 130 or disposed on a surface vessel and includes a main flowline or conduit 171 coupled to the upper end of conduit 123, a fluid supply/suction line 172 in selective fluid communication with main conduit 171, and an injection/suction pump 173 connected to line 172. Conduit 171 has an upper venting end 171a and a lower end 171b in fluid communication with cavity 112' via conduit 123 and port 113'. A valve 174 disposed along conduit 171 controls the flow of

fluid (e.g., mud, water, etc.) through conduit 171 between ends 171a, b - when valve 174 is open, fluid is free to flow through conduit 171 from cavity 112' to venting end 171a, and when valve 174 is closed, fluid is restricted and/or prevented from flowing through conduit 171 from cavity 112' to venting end 171a.

[0034] Pump 173 is configured to pump fluid (e.g., water) into cavity 112' and pump fluid (e.g., water, mud, silt, etc.) from cavity 112' via line 172 and conduit 171. A valve 175 disposed along line 172 controls the flow of fluid through line 172 - when valve 175 is open, pump 173 may pump fluid into cavity 112' via line 172 and conduit 171, or pump fluid from cavity 112' via conduit 171 and line 172; and when valve 175 is closed, fluid communication between pump 173 and cavity 112' is restricted and/or prevented. In this embodiment, pump 173, line 172, and valves 174, 175 are positioned at the surface 11 (e.g., disposed on a deployment vessel or mounted to buoyancy module 130) and conduit 171 extends from the surface 11 to the upper end of conduit 123. For example, suction/injection control system 170 may be disposed on a surface vessel and deployed (i.e., conduit 171 connected to conduit 123) during installation or removal of system 100.

[0035] Referring again to Figure 1, buoyancy module 130 is coupled to the upper end of tension member 120 and is disposed at or proximal the sea surface 11. Although module 130 may be directly attached to the upper end of tension member 120, in this embodiment, module 130 is coupled to the upper end of tension module 120 with a flexible polyester cable 131. Buoyancy module 130 is net buoyant. As previously described, module 130 provide sufficient buoyancy to both support the weight of components coupled thereto and apply tension to tension member 120. Antenna 140 is attached to module 130 and extends upward therefrom above the sea surface 11.

[0036] Referring now to Figure 6, in this embodiment, buoyancy module 130 includes a housing 132 having an upper end 132a, a lower end 132b, and an inner chamber or cavity 133. Housing 132 includes a port 134 proximal lower end 132b such that port 134 is positioned below the sea surface 11 following deployment and installation of system 100. In particular, port 134 is provided in a sidewall of housing 132 axially adjacent lower end 132b. Port 134 places inner chamber 133 in fluid communication with the surrounding environment, and thus, when port 134 is disposed below the sea surface 11, water is allowed to enter and exit inner chamber 133 via port 134. It should be appreciated that flow through port 134 is not controlled by a valve or other flow control device. Thus, port 134 permits the free flow of water into and out of chamber 133.

[0037] The buoyancy of module 130 can be adjusted by ballasting and de-ballasting module 130 to vary the tensile loads exerted on tension member 120. In this embodiment, a ballast control system 135 and port 134 are used to adjust and control the buoyancy of module 130. Ballast control system 135 includes an air conduit 136, an air supply line 137, an air compressor or pump 138 connected to supply line 137, a first valve 139a along line 137 and a second valve 139b along conduit 136. Conduit 136 has a first end 136a above the sea surface 11 external chamber 133 and a second end 136b connected to upper end 132a of housing 132 and in fluid communication with chamber 133. Valve 139b controls the flow of air through conduit 136 between ends 136a, b, and valve 139a controls the flow of air from compressor 138 to chamber 133. Control system 135 allows the relative volumes of air and water in chamber 133 to be controlled and varied, thereby enabling the buoyancy of chamber 133, and hence tension applied to tension member 120, to be controlled and varied. In particular, with valve 139b open and valve 139a closed, air is exhausted from chamber 133, and with valve 139a open and valve 139b closed, air is pumped from compressor 138 into chamber 133. Thus, end 136a functions as an air outlet, whereas end 136b functions as both an air inlet and outlet. With valve 139a closed, air cannot be pumped into chamber 133, and with valves 139a, 139b closed, air cannot be exhausted from chamber 133.

[0038] In this embodiment, end 139b is disposed at upper end of chamber 133 and port 134 is positioned proximal the lower end of chamber 133. This positioning of open end 139b enables air to be exhausted from chamber 133 when housing 132 is in a generally vertical, upright position (e.g., following installation). In particular, since air is less dense than water, any air in chamber 133 will naturally rise to the upper portion of chamber 133 above any water in chamber 133 when housing 132 is upright. Accordingly, positioning end 139b at or proximal the upper end of chamber 133 allows direct access to any air therein. Further, since water in chamber 133 will be disposed below any air therein, positioning port 134 proximal the lower end of chamber 133 allows ingress and egress of water, while limiting and/or preventing the loss of any air through port 134. In general, air will only exit chamber 133 through port 134 when chamber 133 is filled with air from the upper end of chamber 133 to port 134. Positioning of port 134 proximal the lower end of chamber 133 also enables a sufficient volume of air to be pumped into chamber 133. In particular, as the volume of air in chamber 133 is increased, the interface between water and the air will move downward within chamber 133 as the increased volume of air in chamber 133 displaces water in chamber 133, which is allowed to exit chamber through port 134. However, once the interface of water and the air reaches port 134, the volume of air in chamber 133 cannot be increased further as any additional air will simply exit chamber 133

through port 134. Thus, the closer port 134 to the lower end of chamber 133, the greater the volume of air that can be pumped into chamber 133, and the further port 134 from the lower end of chamber 133, the lesser the volume of air that can be pumped into chamber 133. Thus, the vertical/axial position of port 134 along chamber 133 is preferably selected to enable the maximum desired buoyancy for module 130.

[0039] In this embodiment, pump 138, line 137, and valves 139a, 139b are positioned at the surface 11. For example, system 135 can be mounted to module 130 or disposed on a surface vessel and deployed (i.e., conduit 136 connected to module 130) during installation of system 100.

[0040] Referring again to Figures 1 and 2, stringers 150 are circumferentially spaced about tension member 120 and extend from buoyancy module 130 to the sea floor 10. In particular, each stringer 150 has an upper end coupled to module 130 and a lower end secured to the sea floor 10 radially spaced away from base 110 and tension member 120. In general, stringers 150 may be coupled to module 130 and the sea floor 10 by any means known in the art. For example, the lower ends of stringers 150 may be coupled to the sea floor 10 with gravity anchors, driven piles, etc. In this embodiment, each stringer 150 is a single flexible composite tubular member 121 as previously described.

[0041] A plurality of instrumentation packages or systems 151 are coupled to and supported by stringers 150. In general, systems 151 may comprise any instrument(s) or system(s) for detecting, measuring, and gathering data relating to the surrounding environment and/or subsea geological formations such as seismic systems (e.g., marine seismic source(s) and associated receivers) and oceanographic instrument packages. In general, the same or different types of instrumentation systems 151 may be mounted to the same stringer 151. Accordingly, stringers 150 and associated systems 151 may be described as forming an instrument array. The data measured and detected by systems 151 is communicated to antenna 140, which then retransmits the data via satellite or any other means to any desired location (e.g., a vessel, aircraft, onshore location, etc.) for further processing, review, analysis or combinations thereof. In general, the data may be communicated from systems 151 to antenna 140 by any suitable means including, without limitation, wires, fiber optic lines, wireless technologies (e.g., acoustic telemetry), or combinations thereof. In this embodiment, systems 151 communicate with antenna 140 via fiber optics cables run through the corresponding stringer 150 to module 130 and antenna 140. Select systems 151 may communicate indirectly with antenna 140 through one or more other systems 151. For example, select systems 151 may communicate wirelessly to other systems 151, which in turn

communicate with antenna 140, thereby reducing the need for every system 151 to independently and directly communicate with antenna 140. To minimize the weight of stringers 150, fiber optic or wireless technologies are preferably employed. For wired or fiber optic communication, the wires or fiber optic lines are preferably run through the central through bore of the corresponding stringer 150 to buoyancy module 130 and antenna 140.

[0042] It should be appreciated that systems 151 may be positioned at any desired location along stringers 150, and thus, systems 151 can be used to collect data at any one or more desired depth(s) below the sea surface 11. In addition, since stringers 150 extend to the sea floor 10 in this embodiment, systems 151 designed for seismic investigation can be positioned at or proximal the sea floor 10 as desired.

[0043] Although each stringer 150 extends from buoyancy module 130 to floor 10 in this embodiment, in other embodiments, one or more of the stringers (e.g., stringers 150) may not extend completely to the sea floor, may extend from a location along the tension member (e.g., tension member 120) below the buoyancy module (e.g., buoyancy module 130), or combinations thereof. Further, although systems 151 are mounted to stringers 150 in this embodiment, in other embodiments, one or more instrumentation systems (e.g., systems 151) are mounted to the tension member (e.g., tension member 120). In some embodiments, a portion of one or more stringers (e.g., strings 150) may be disposed along the sea floor and/or be directly secured to the tension member (e.g., tension member 120).

[0044] In general, the power to operate the various systems and components of system 100 (e.g., systems 151, antenna 140, etc.) may be provided by any suitable means including, without limitation, batteries, generator(s) (e.g., wave energy generators, wind energy generators, etc.), or solar panels. Since systems 135, 170 are generally only used during deployment, they may be disposed on vessel 200 and coupled to module 130 and conduit 123, respectively, during installation of system 100.

[0045] Referring now to Figures 7A-7F, the deployment of system 100 is shown. In Figures 7A and 7B, base 110 is shown being lowered subsea with tension member 120; in Figures 7C-7E, base 110 is shown being embedded in the sea floor to anchor tension member 120 thereto; in Figure 7F, buoyancy module 130, including antenna 140, is shown mounted to the upper end of tension member 120; and in Figure 7G, stringers 150 are shown coupled to buoyancy module 130 to form system 100. In this embodiment, system 100 is deployed in stages from a surface vessel 200. In particular, vessel 200 includes a plurality of spools 210 of tension members 120 and a plurality of spools 211 of stringers 150. In general, stringers 150 can be pre-configured to include systems 151 (i.e., systems 151 are mounted to the

spooled stringers 150), systems 151 can be installed on stringers 150 as stringers 150 are deployed from spools 211, or systems 151 can be installed on stringers 150 after deployment (e.g., via subsea ROVs and/or divers).

[0046] Referring first to Figure 7A, on vessel 200, base 110 is secured to the end of a tension member 120 mounted to spool 210. Next, base 110 is hung from tension member 120 and placed in the water. Moving now to Figure 7B, base 110 is lowered subsea as tension member 120 is paid out from spool 210. As base 110 is submerged, water floods housing 111 via port 114. Base 110 is lowered subsea until it engages the sea floor 10 as shown in Figure 7C. Next, as shown in Figure 7D, a heavy slurry 250 (e.g., iron ore-water mixture or heavy drilling mud) is pumped from vessel 200 down conduit 123 into chamber 112. Slurry 250 has a density greater than water, and thus, settles in the bottom of housing 111. As slurry 250 fills housing 111, water in housing 111 is displaced by the slurry 250 and exits chamber 112 via port 114. Due to the added weight of slurry 250, base 110 begins to settle and embed itself into the sea floor 10 as shown in Figures 7D and 7E. Once base 110 is sufficient seated on the sea floor 10, pumping of slurry 250 is ceased.

[0047] Referring now to Figure 7F, with base 110 secured to the sea floor 10, buoyancy module 130, with antenna 140 mounted thereto, is coupled to the upper end of tension member 120. System 135 is used to adjust the buoyancy of module 130 to apply the desired tensile force to tension member 120. Moving now to Figure 7G, stringers 150 are then paid out from spools 211, one end of each stringer 150 is coupled to buoyancy module 130, and the other end of each stringer 150 is secured to the sea floor 10. The buoyancy of module 130 can be adjusted with system 135 to support the added weight as stringers 150 are hung from module 130. If stringers 150 are not pre-configured to include systems 151, systems 151 are installed during deployment of stringers 150 or after deployment of stringers 150.

[0048] Referring now to Figures 8A and 8B, in embodiments where base 110' is employed in system 100, suction/injection control system 170 facilitates the insertion of skirt 111' into the sea floor 10 during deployment of system 100. In particular, as skirt 111' is pushed into sea floor 10, valve 174 may be opened and valve 175 closed to allow water 101 within cavity 112' between sea floor 10 and upper end 111a' to vent through conduit 171 and out end 171a. To accelerate the penetration of skirt 111' into sea floor 10 and/or to enhance the "grip" between suction skirt 111' and the sea floor 10, suction may be applied to cavity 112' via pump 173, conduit 171 and line 172. In particular, valve 175 may be opened and valve 174 closed to allow pump 173 to pull fluid (e.g., water, mud, silt, etc.) from cavity 112' through conduit 171 and line 172. Once skirt 111' has penetrated the sea floor 10 to the desired depth, valves 174, 175 are

preferably closed to maintain the positive engagement and suction between anchor 140 and the sea floor 10.

[0049] To pull and remove anchor 140 from the sea floor 10 (e.g., to remove system 100), valve 174 may be opened and valve 175 closed to vent cavity 112' and reduce the hydraulic lock between skirt 111' and the sea floor 10. To accelerate the removal of skirt 111' from sea floor 10, fluid may be pumped into cavity 112' via pump 173, conduit 171 and line 172. In particular, valve 175 may be opened and valve 174 closed to allow pump 173 to inject fluid (e.g., water) into cavity 112' through conduit 171 and line 172.

[0050] As shown in Figures 7A-7C, during installation of system 100 from vessel 200, flexible tension member 120 is allowed to slide across a smoothly curved convex surface along the bow of vessel 200 as base 110 is lowered subsea. During deployment from spool 210, tension member 120 is in tension and a braking mechanism on spool 210 is used to controllably pay out tension member 120. Likewise, during deployment from spool 220, stringers 150 are in tension and a braking mechanism on spool 211 is used to controllably pay out stringers 150. However, in other embodiments, alternative devices may be employed to control the pay out of tension member 120 and/or stringers 150. For example, in Figure 9, a device or shoe 300 for managing the deployment of tension member 120 is shown. In this embodiment, deployment device 300 includes a base 301, a curvature control member 310 extending from the upper end of base 301, and a tensioner 320 mounted to base 301. Base 301 is securely mounted to vessel 200 adjacent spool 210. Tension member 120 extends from spool 210 around curvature control member 310, through tensioner 320, and over the side of vessel 200. Curvature control member 310 is a rigid, arcuate tray that guides tension member 120 to tensioner 320 and aligns tension member 120 with tensioner 320. In addition, curvature control member 310 maintains a minimum radius of curvature for tension member 120 so as to avoid kinks in or damage to tension member 120 during deployment. Tensioner 320 grips tension member 120, and controls the pay out of tension member 120 from spool 210, thereby reducing and/or eliminating the need for a braking mechanism on spool 210. In this embodiment, tensioner 320 supports the load of tension member 120 and base 110 coupled thereto and includes a plurality of circumferentially spaced flexible tracks 321 that engage and grip tension member 120. Each track 321 is mounted to a pulley 322 and a drive sprocket 323 that drives the movement of the corresponding track 321. Tracks 321 are biased and/or urged radially inward into firm engagement with tension member 120 and preferably comprise a flexible, resilient material that can grip tension member 120 without damaging it such as an elastomer or natural rubber material.

[0051] Referring still to Figure 9, tension member 120 is run from spool 210 around curvature control member 310 and in between tracks 321, which engage and grip tension member 120. To pay out tension member 120 from spool 210, drive sprockets 323 are rotated to controllably move tracks 321. The frictional engagement of tracks 321 and tension member 120 is sufficient to support the load of tension member 120 and base 110 without allowing tension member 120 to slip and slide through tensioner 320. Although device 300 is shown in connection with spool 210 and tension member 120 mounted thereto, it can also be used in the same manner as described above to controllably pay out stringer(s) 150 from spools 211.

[0052] Although only one system 100 is shown in Figures 1 and 2, it should be appreciated that a plurality of systems 100 can be deployed at a plurality of different offshore locations to collect environmental and geological data from such different locations. Such systems 100 may communicate with each other (e.g., directly or through one or more intermediate communication connections such as a satellite).

[0053] While preferred embodiments have been shown and described, modifications thereof can be made by one skilled in the art without departing from the scope or teachings herein. The embodiments described herein are exemplary only and are not limiting. Many variations and modifications of the systems, apparatus, and processes described herein are possible and are within the scope of the invention. For example, the relative dimensions of various parts, the materials from which the various parts are made, and other parameters can be varied. Accordingly, the scope of protection is not limited to the embodiments described herein, but is only limited by the claims that follow, the scope of which shall include all equivalents of the subject matter of the claims. Unless expressly stated otherwise, the steps in a method claim may be performed in any order. The recitation of identifiers such as (a), (b), (c) or (1), (2), (3) before steps in a method claim are not intended to and do not specify a particular order to the steps, but rather are used to simplify subsequent reference to such steps.

CLAIMS

What is claimed is:

1. A system for acquiring data in an offshore environment, the system comprising:

an elongate composite tension member having a longitudinal axis, an upper end, and a lower end;

a buoyancy module coupled to the upper end of the composite tension member and configured to apply a tensile load to the tension member;

a base coupled to the lower end of the composite tension member, the base configured to secure the tension member to the sea floor;

a plurality of composite stringers coupled to the buoyant module and disposed about the tension member; and

a plurality of instrumentation systems configured to measure environmental or geological data, wherein the instrumentation systems are coupled to the stringers.

2. The system of claim 1, further comprising a communication antenna coupled to the buoyant module, wherein the antenna is configured to wirelessly communicate the data measured by the instrumentation systems.

3. The system of claim 1, wherein instrumentations systems are disposed at a plurality of different axial positions along the stringers.

4. The system of claim 3, wherein the instrumentation systems are configured to measure environmental data at different depths below the sea surface.

5. The system of claim 1, wherein the composite tension member comprises a flexible pultruded fiberglass composite tubular member.

6. The system of claim 1, wherein the composite tension member comprises a bundle of parallel tubular members.

7. The system of claim 6, wherein the bundle of tubular members includes a plurality of flexible pultruded fiberglass composite tubular members and a flexible fluid conduit disposed

within an interstitial space between the composite tubular members.

8. The system of claim 7, wherein the base is a gravity anchor comprising a housing having an internal chamber in fluid communication with the fluid conduit of the tension member.

9. The system of claim 8, wherein the housing includes a port configured to allow fluid communication between the internal chamber and the surrounding environment, wherein the port is positioned proximal an upper end of the housing.

10. The system of claim 7, wherein the base is a suction pile comprising a skirt having an enclosed upper end, an open lower end, and an inner chamber in fluid communication with the fluid conduit of the tension member.

11. The system of claim 1, wherein the buoyancy module is adjustably buoyant.

12. The system of claim 1, wherein at least two of the instrumentation systems are configured to wirelessly communicate with each other.

13. The system of claim 1, wherein the tension member has a length-to-width ratio greater than 500.

14. A system for acquiring environmental and/or geological data in an offshore environment, the system comprising:

an elongate tension member having a longitudinal axis, an upper end, and a lower end, wherein the tension member comprises a plurality of parallel flexible composite tubular members;

an adjustably buoyant module coupled to the upper end of the tension member and configured to apply a tensile load to the tension member;

a base coupled to the lower end of the composite tension member, the base configured to secure the tension member to the sea floor;

a plurality of stringers coupled to the adjustably buoyant module and configured to extend subsea; and

a plurality of instrumentation systems for measuring the environmental and/or

geological data, wherein the instrumentation systems are coupled to the stringers.

15. The system of claim 14, further comprising a communication antenna coupled to the buoyant module, wherein the antenna is configured to communicate the data measured by the instrumentation systems to a satellite.

16. The system of claim 14, wherein instrumentations systems are disposed at a plurality of different axial positions along the stringers.

17. The system of claim 14, wherein each composite tubular member comprises a pultruded fiberglass composite.

18. The system of claim 14, wherein at least one of the stringers is configured to extend to the sea floor.

19. The system of claim 14, wherein the tension member includes a flexible fluid conduit disposed between the composite tubular members.

20. The system of claim 14, wherein the base is a gravity anchor or a suction pile.

21. A method for acquiring environmental and/or geological data in an offshore environment, the method comprising:

(a) coupling a base to a first end of an elongate tension member;

(b) lowering the base to the sea floor with the tension member;

(c) coupling a buoyancy module to a second end of the tension member;

(d) coupling a plurality of instrumentation systems to a plurality of stringers, wherein the instrumentation systems are configured to acquire subsea environmental data and/or geological data;

(e) adjusting the buoyancy of the buoyancy module;

(f) coupling the plurality of stringers to the buoyancy module, wherein each stringer has an upper end coupled to the buoyancy module and a lower end disposed subsea.

22. The method of claim 21, wherein (b) further comprises paying out the tension member from a spool disposed on a surface vessel.

23. The method of claim 21, wherein the tension member and the stringers comprises composite tubular members.

24. The method of claim 21, wherein the base comprises a gravity anchor or a suction pile.

25. The method of claim 24, wherein the tension member includes a fluid conduit extending from the first end to the second end, wherein the fluid conduit is in fluid communication with an internal chamber of the base.

26. The method of claim 25, wherein the base is a gravity anchor and wherein (b) further comprises pumping a slurry have a density greater than water from the surface and through the tension member into the internal chamber of the base.

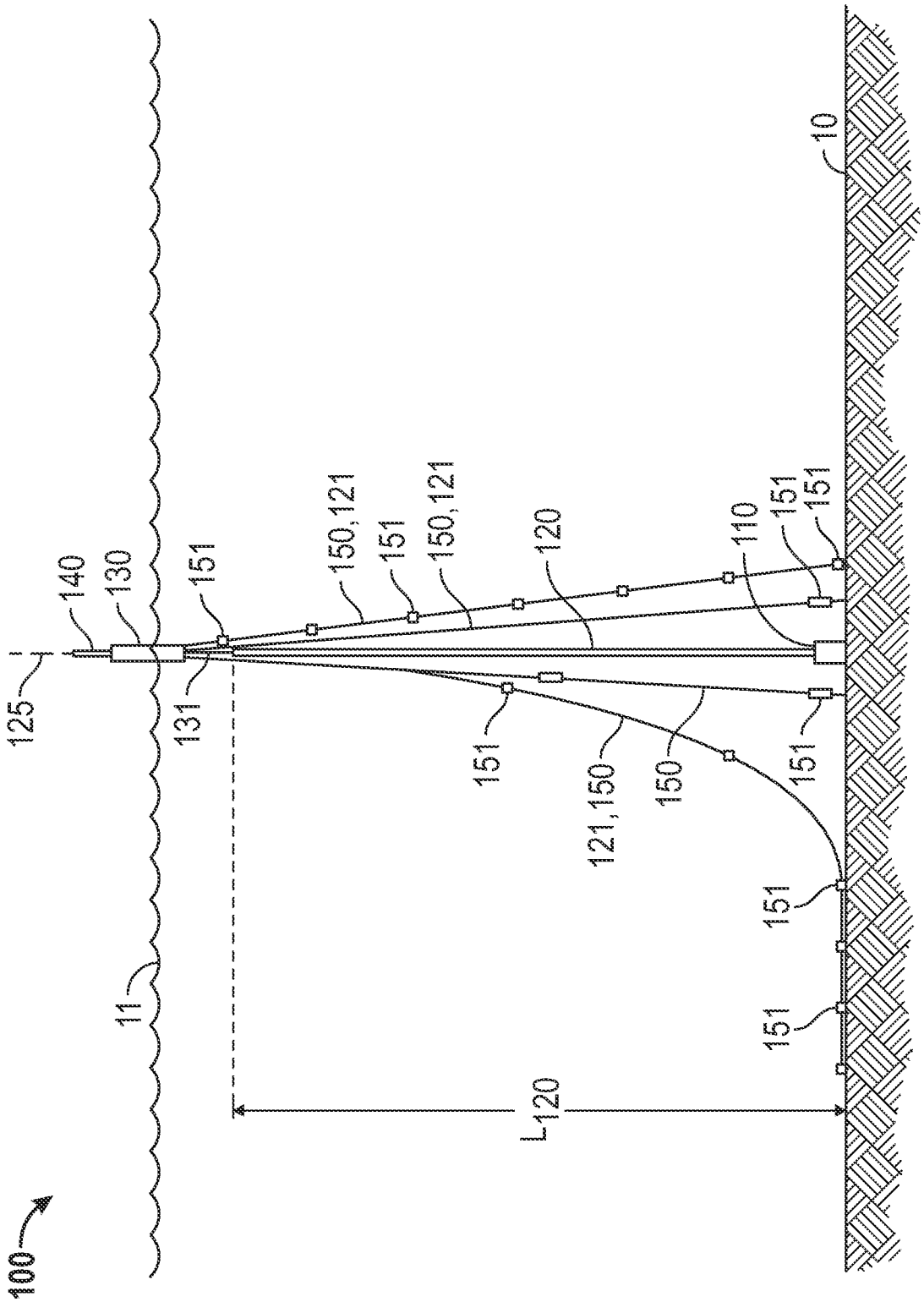

100
125
140
130
131
151
150,121
151
150,121
120
110
151
151
151
151
121,150
150
151
151
151
11
10
L120

FIG. 1

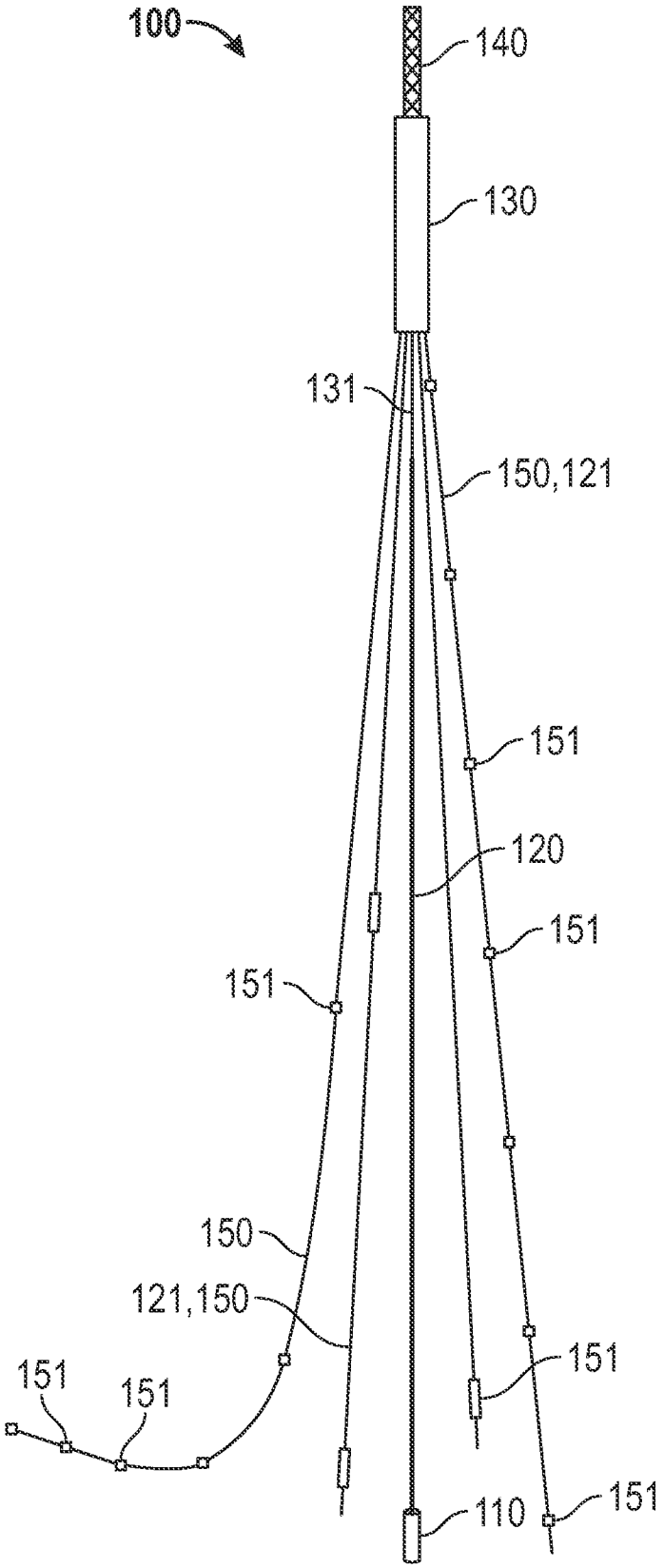

100
140
130
131
150,121
151
120
151
151
150
121,150
151
151
151
110
151

FIG. 2

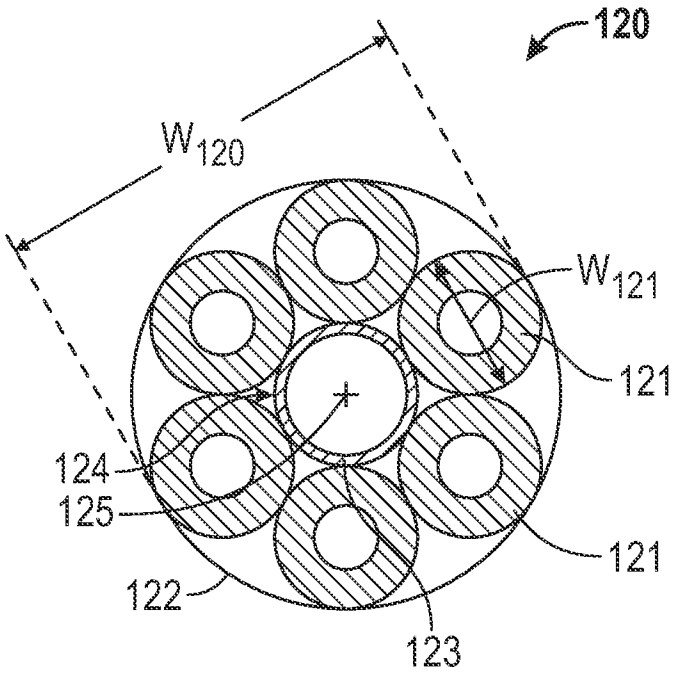

120
W_{120}
W_{121}
121
124
125
121
122
123

FIG. 3

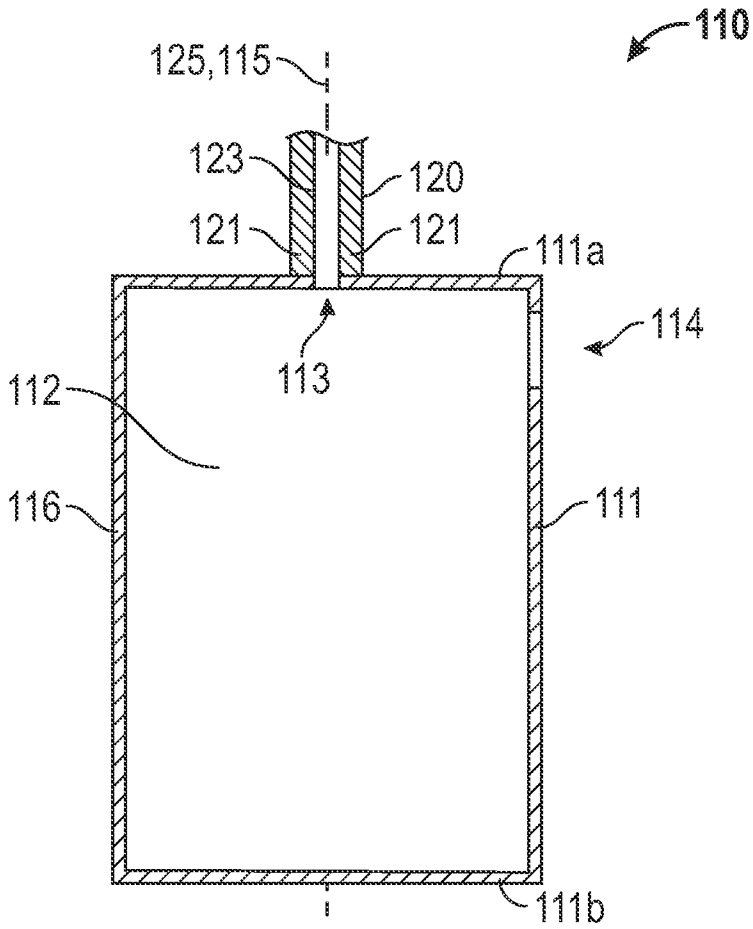

110
125,115
123
120
121
121
111a
114
113
112
116
111
111b

FIG. 4

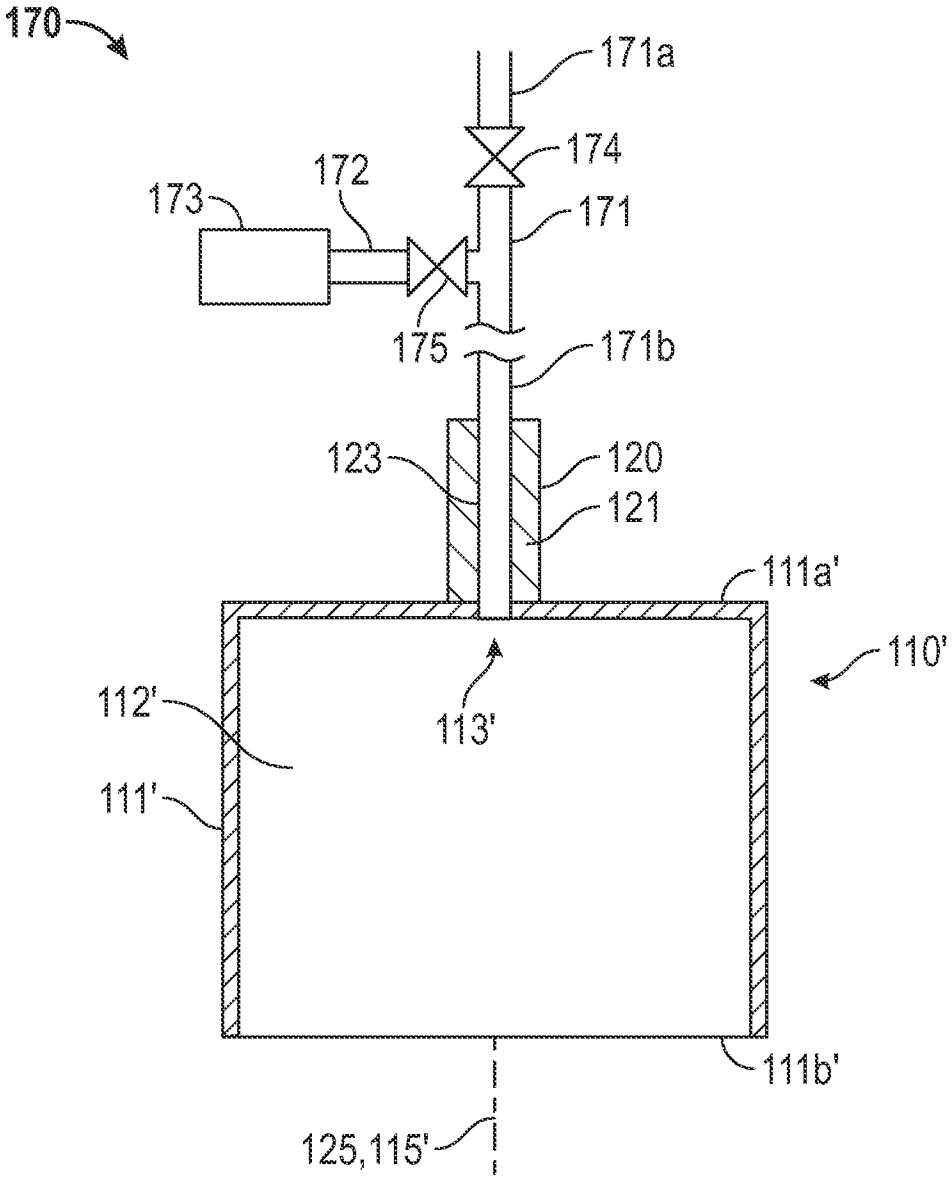

170
171a
174
172
173
171
175
171b
123
120
121
111a'
110'
112'
113'
111'
111b'
125,115'

FIG. 5

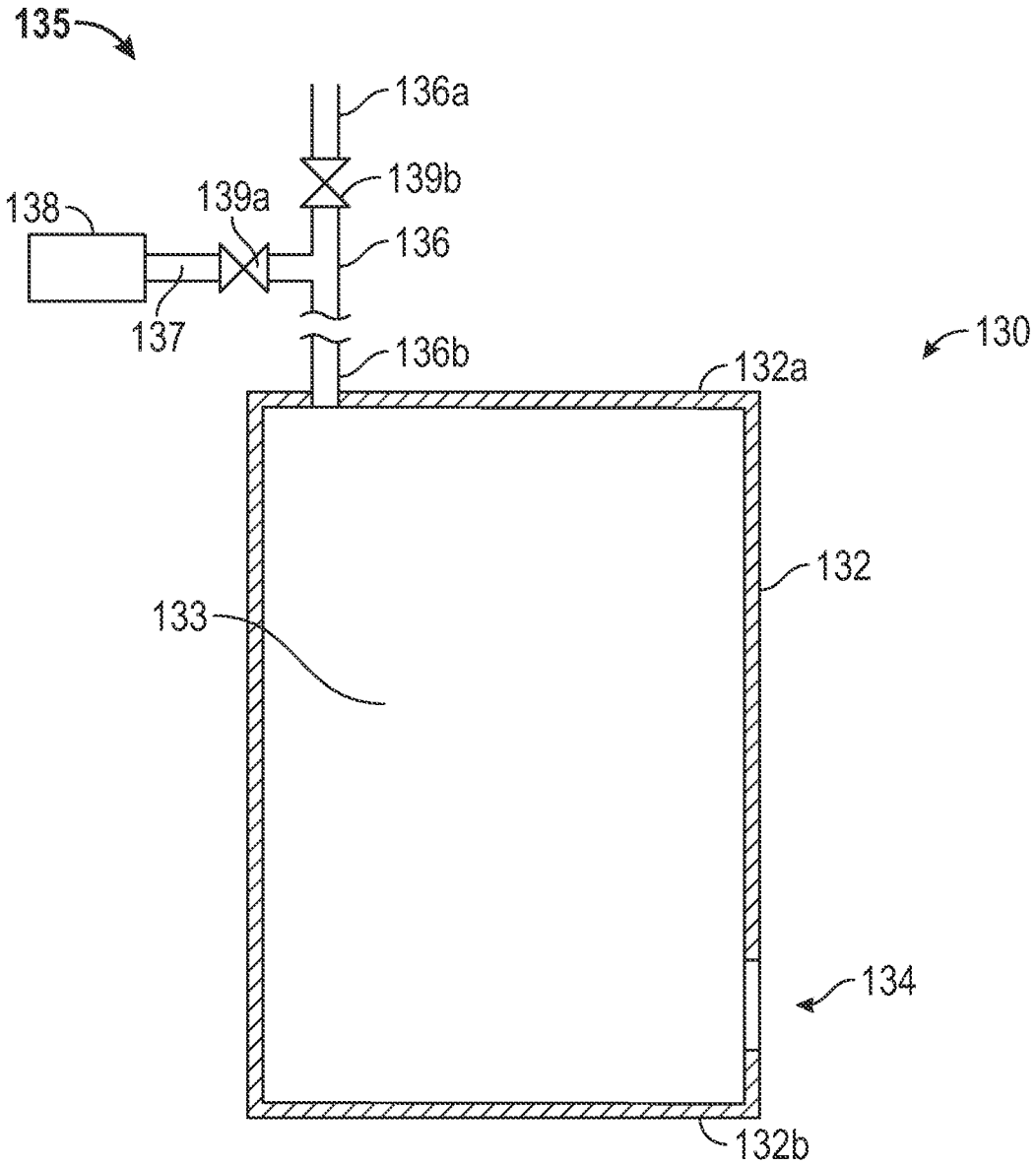


FIG. 6

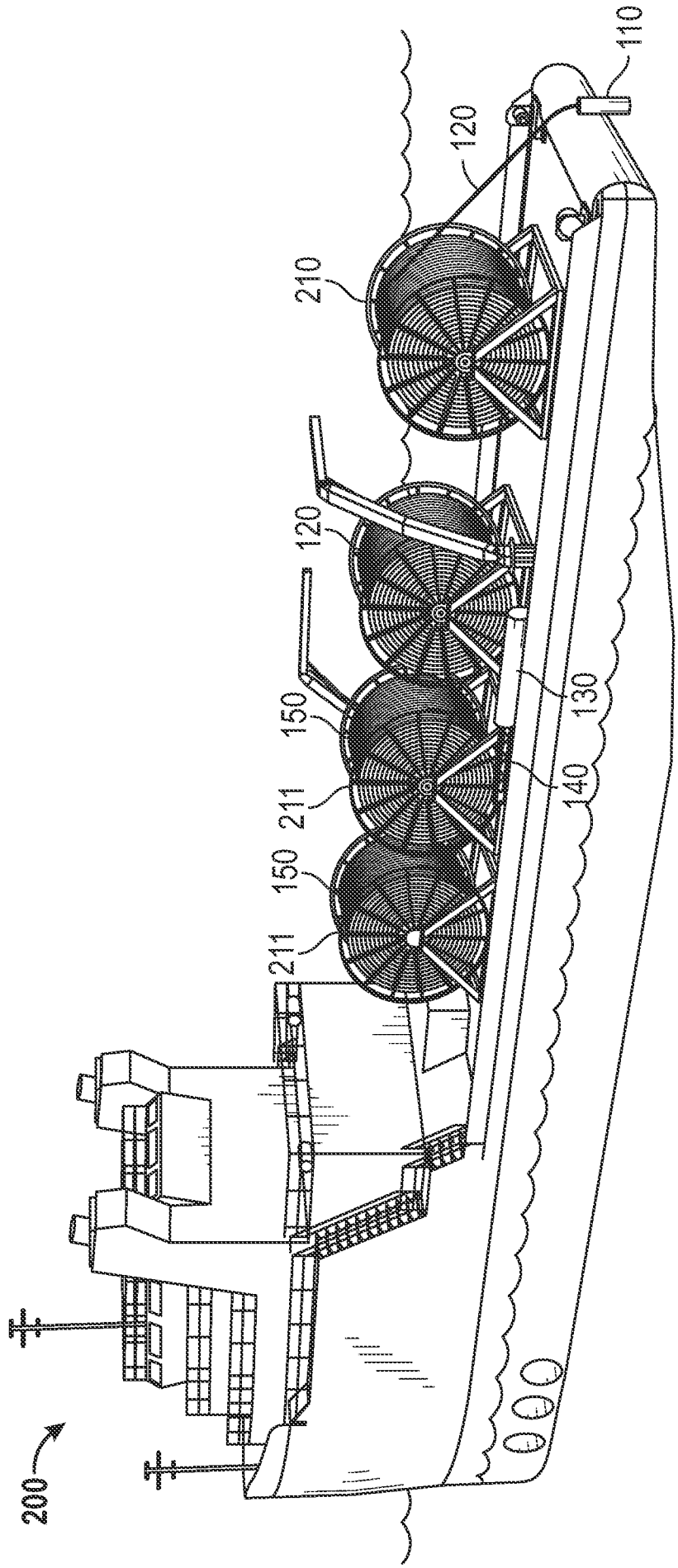


FIG. 7A

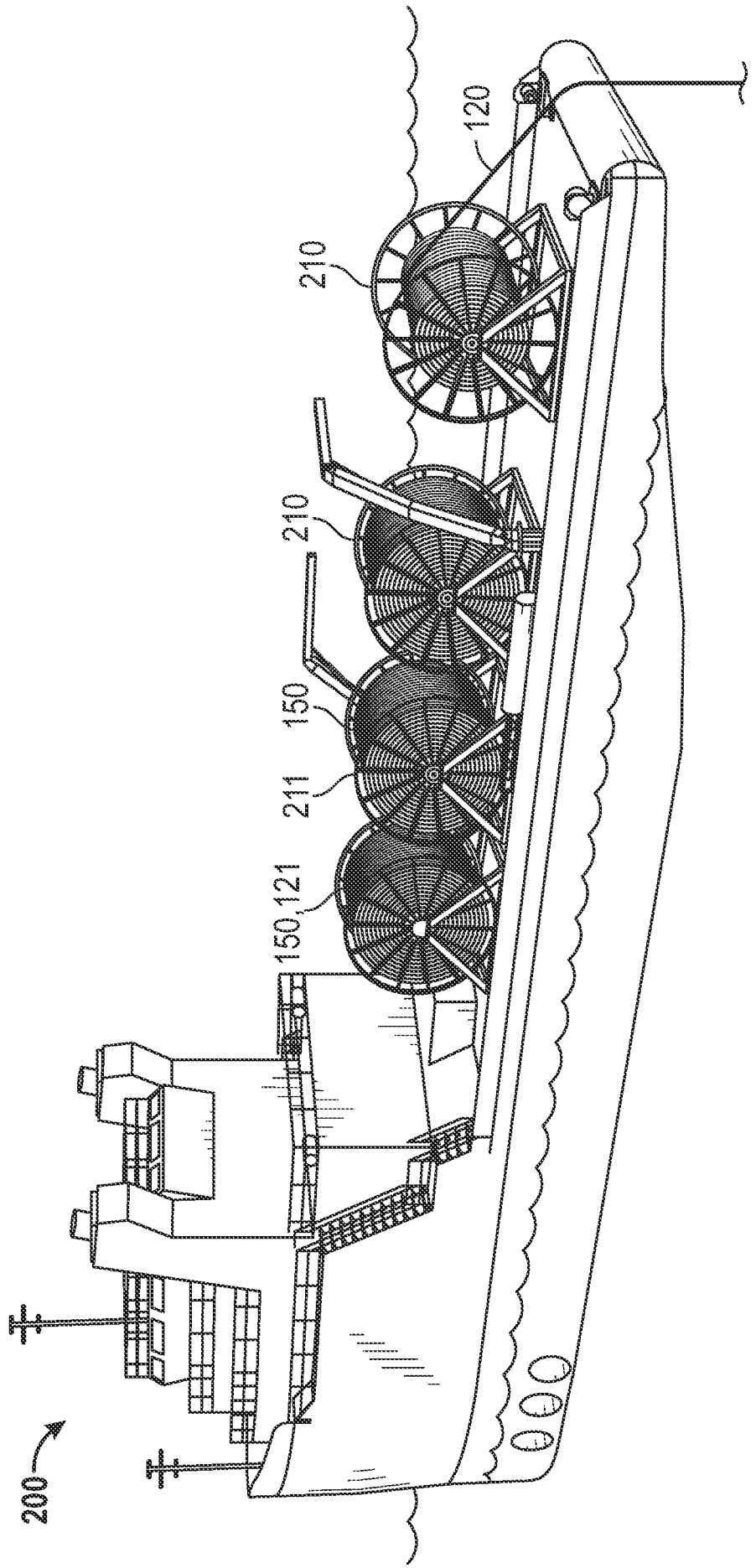


FIG. 7B

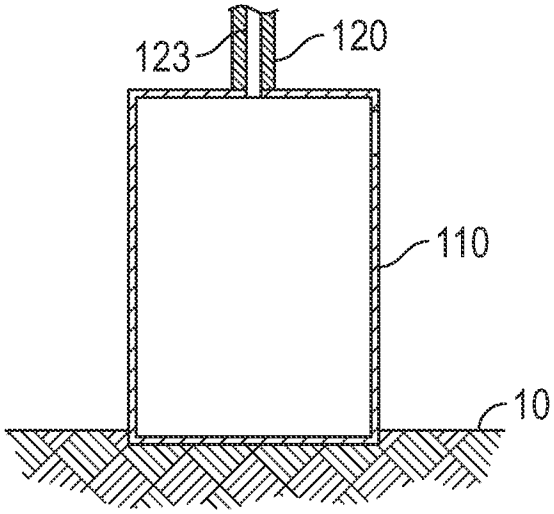


FIG. 7C

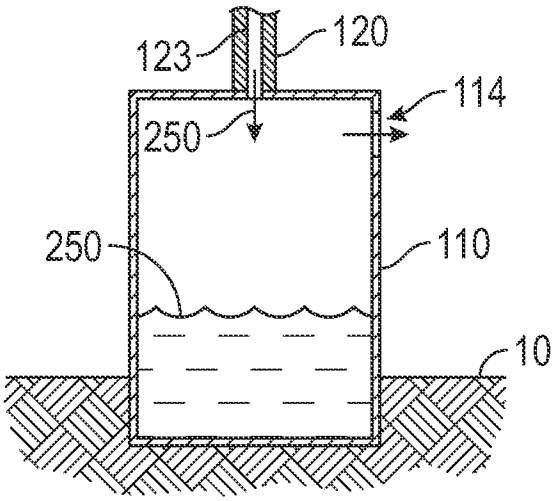


FIG. 7D

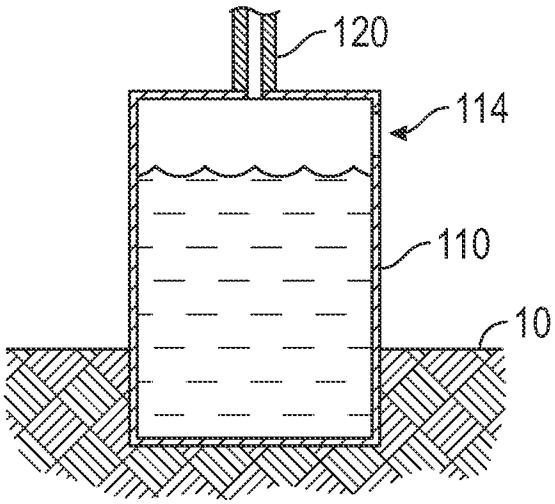


FIG. 7E

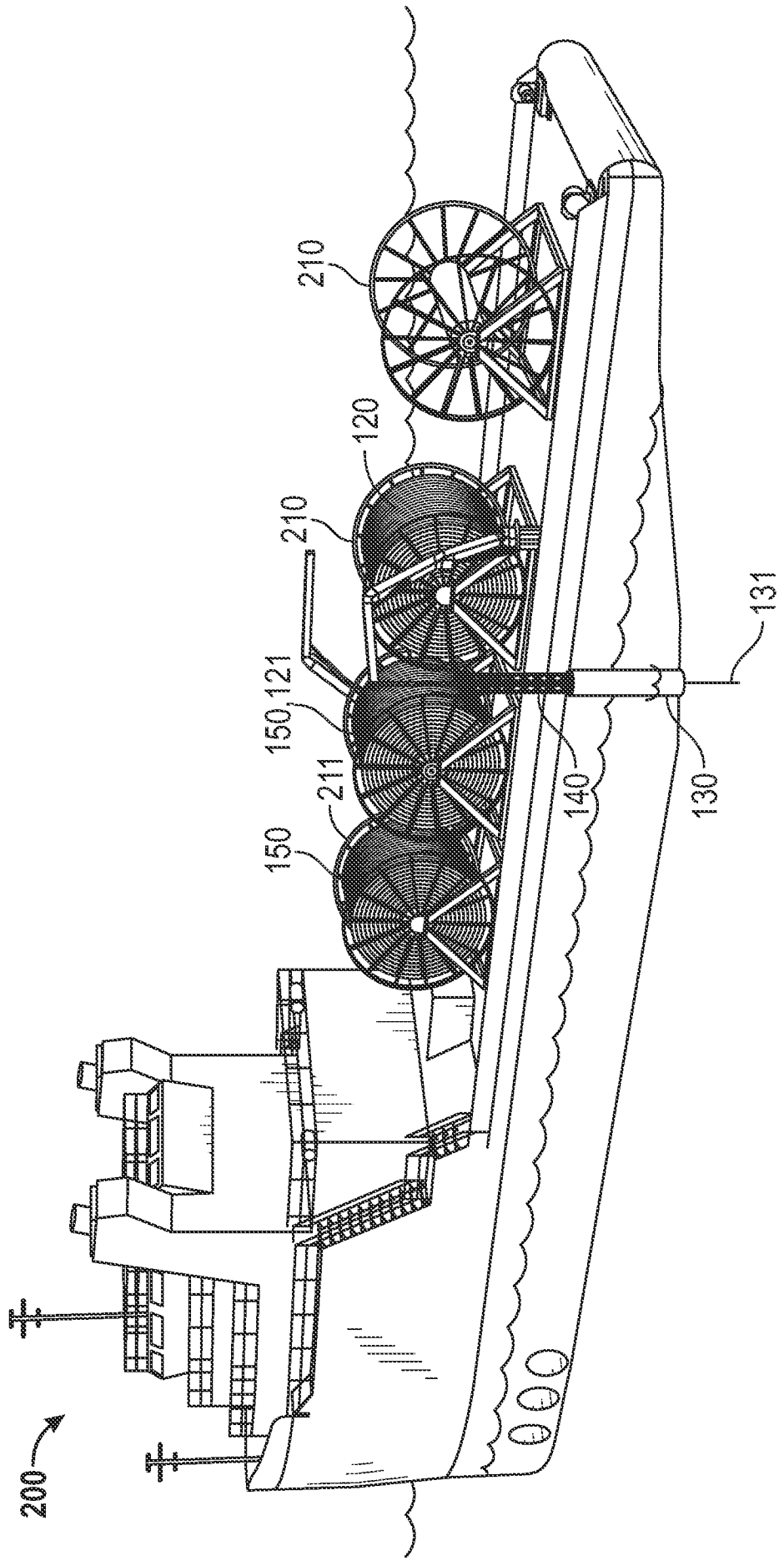


FIG. 7F

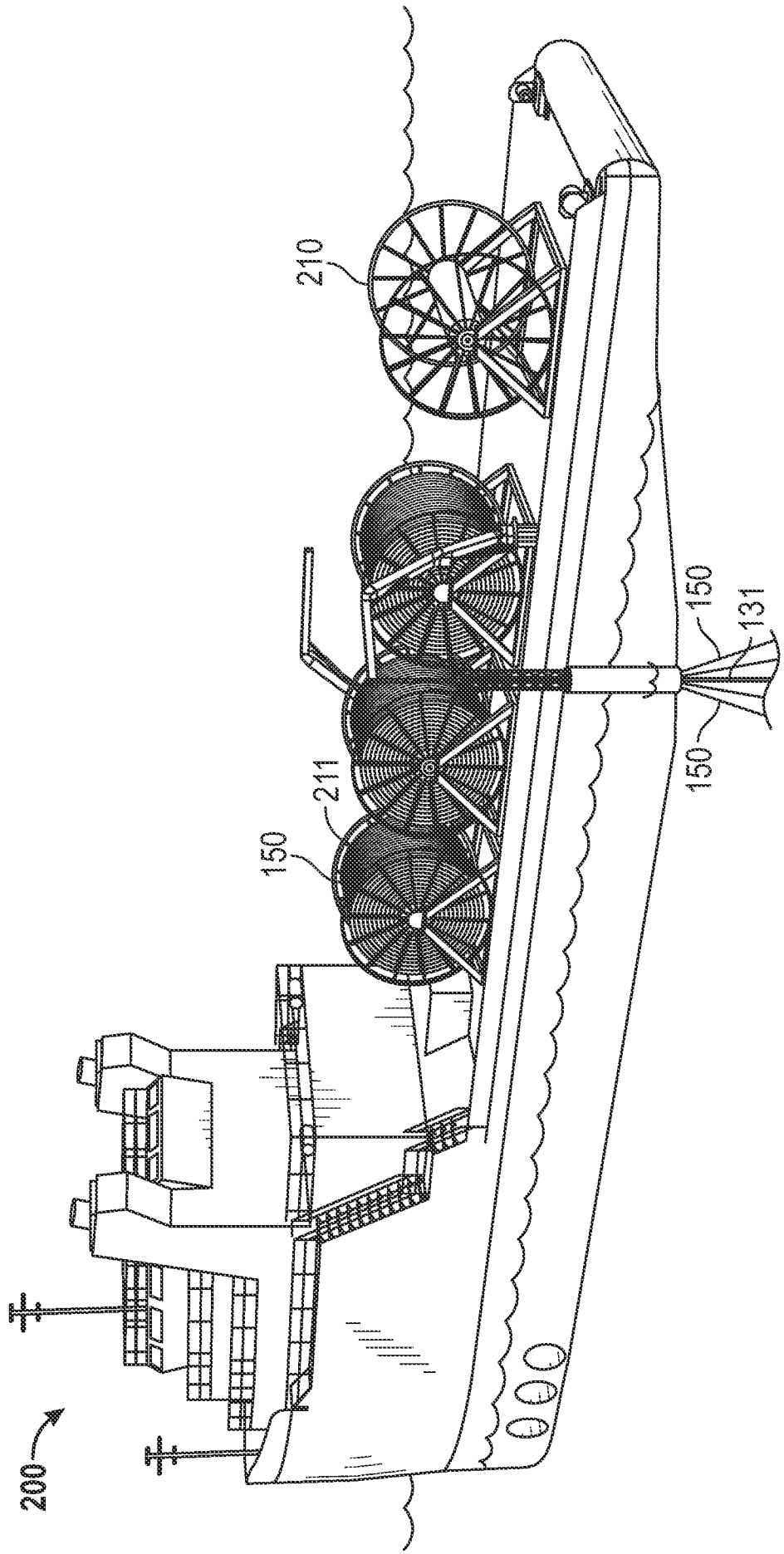


FIG. 7G

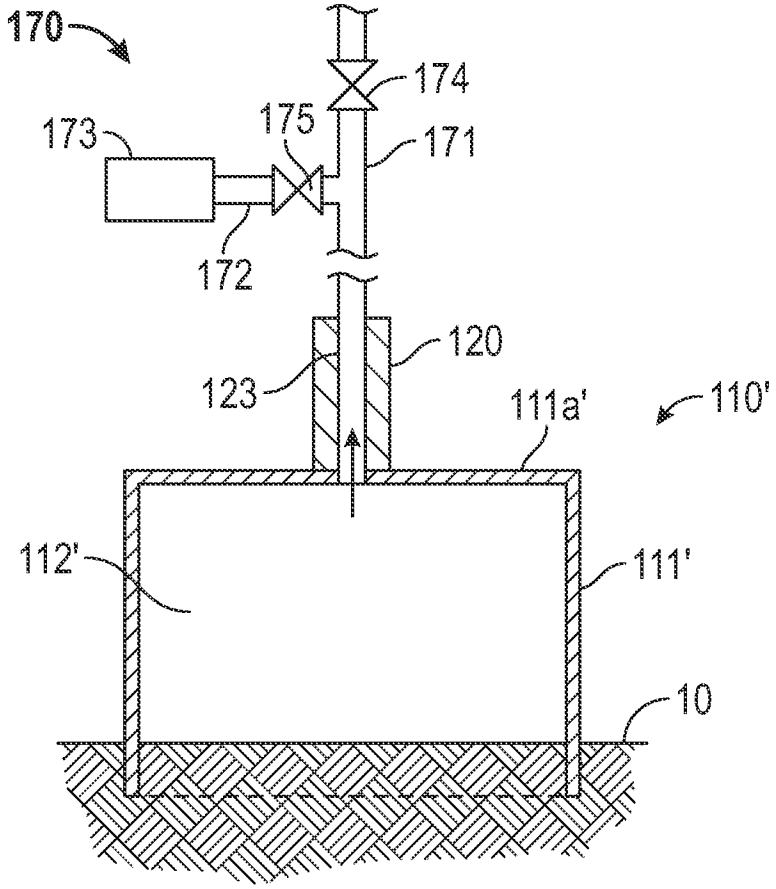

170
174
173
175
171
172
120
123
111a'
110'
112'
111'
10

FIG. 8A

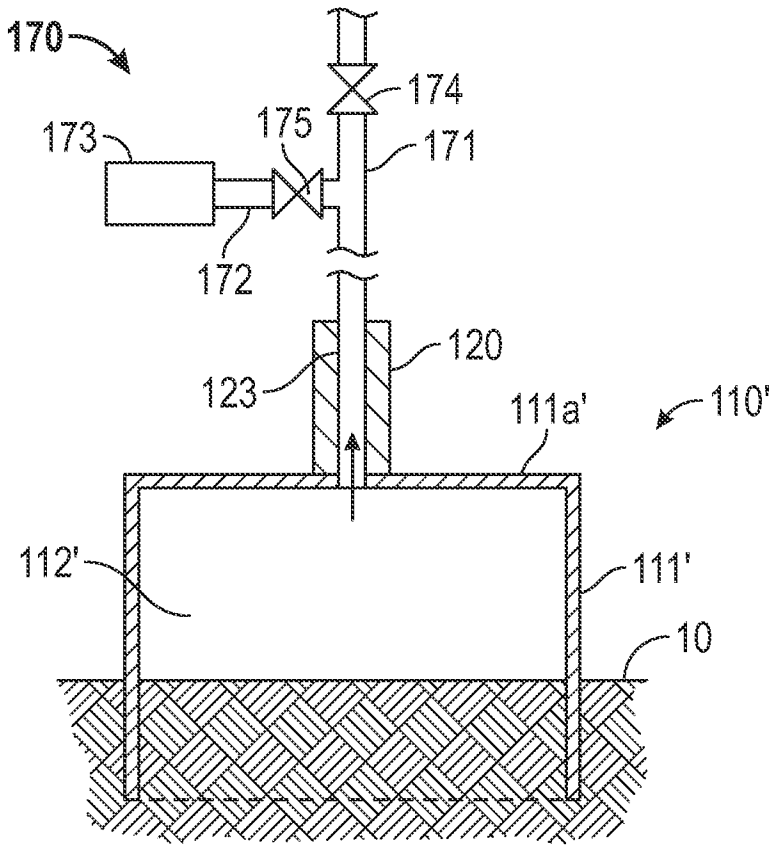

170
174
173
175
171
172
120
123
111a'
110'
112'
111'
10

FIG. 8B

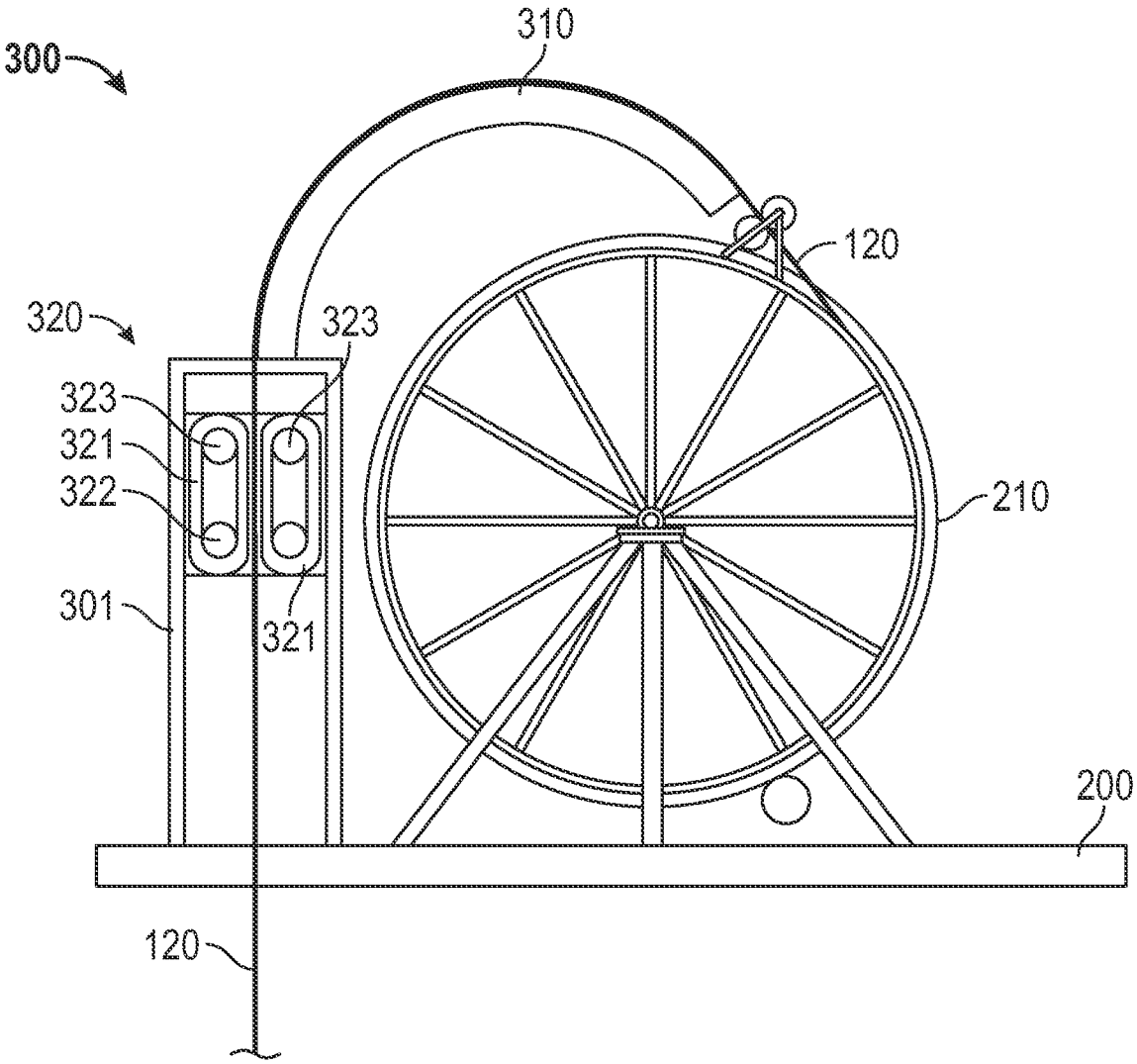


FIG. 9