

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
30 July 2009 (30.07.2009)

PCT

(10) International Publication Number
WO 2009/094353 A1

(51) International Patent Classification:
E02D 5/60 (2006.01)

[US/US]; 4109 Tawakon Drive, Pearland, Texas 77584 (US).

(21) International Application Number:
PCT/US2009/031501

(74) Agent: **HICKMAN, William, E.**; Shell Oil Company, One Shell Plaza, P.O. Box 2463, Houston, Texas 77252-2463 (US).

(22) International Filing Date: 21 January 2009 (21.01.2009)

(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, 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, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/022,873 23 January 2008 (23.01.2008) US

(71) Applicant (for SM only): **SHELL OIL COMPANY** [US/US]; One Shell Plaza, P.O. Box 2463, Houston, Texas 77252-2463 (US).

(71) Applicant (for all designated States except US): **SHELL INTERNATIONALE RESEARCH MAATSCHAPPIJ B.V.** [NL/NL]; Carel van Bylandtlaan 30, NL-2596 HR The Hague (NL).

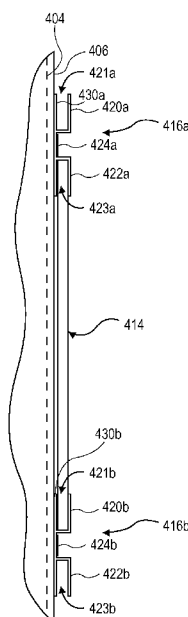
(72) Inventors; and

(75) Inventors/Applicants (for US only): **ALLEN, Donald, Wayne** [US/US]; 4323 Lake Kempt Ct., Richmond, Texas 77469 (US). **ARMSTRONG, Stephen, Paul** [US/US]; 1719 Prairie Mark Lane, Houston, Texas 77077 (US). **MCMILLAN, David, Wayne** [US/US]; 1502 Tulsa, Deer Park, Texas 77536 (US). **WEST, Christopher, Steven**

Published:
— with international search report

(54) Title: VORTEX INDUCED VIBRATION SYSTEMS AND METHODS

FIG. 4b



(57) Abstract: A system comprising a subsea structure defining an interior of the system, the structure subject to a water current; a holder exterior to the subsea structure, the holder comprising at least one guide member, the guide member comprising at least one bearing surface; and a vortex induced vibration suppression device exterior to the subsea structure, a portion of the suppression device interfacing with the bearing surface, so that the suppression device is adapted to weathervane about the subsea structure.

VORTEX INDUCED VIBRATION SYSTEMS AND METHODS

Field of the Invention

This invention is related to vortex induced vibration suppression devices that can be attached to offshore structures to reduce drag and/or vortex induced vibration (VIV).

Background of the Invention

This case is related to co-pending U.S. Application 60/938,125, having attorney docket number TH 3105. U.S. Application 60/938,125 is herein incorporated by reference in its entirety.

Whenever a bluff body in a fluid environment, such as a cylinder, is subjected to a current in the fluid, it is possible for the body to experience vortex-induced vibrations (VIV). These vibrations may be caused by oscillating hydrodynamic forces on the surface which can cause substantial vibrations of the structure, especially if the forcing frequency is at or near a structural natural frequency.

Drilling for and/or producing hydrocarbons or the like from subterranean deposits which exist under a body of water exposes underwater drilling and production equipment to water currents and the possibility of VIV. Equipment exposed to VIV may include structures ranging from the smaller tubes of a riser system, anchoring tendons, or lateral pipelines to the larger underwater cylinders of the hull of a minispar or spar floating production system (a "spar").

Risers as used herein are defined to be a non-exclusive example of a marine element subject to VIV. Generally a riser system is used for establishing fluid communication between the surface and the bottom of a water body. The principal purpose of the riser is to provide a fluid flow path between a drilling vessel and a well bore and to guide a drill string to the well bore.

A typical riser system may include one or more fluid-conducting conduits that extend from the surface to a structure (e.g., wellhead) on the bottom of a water body. For example, in the drilling of a submerged well, a drilling riser usually consists of a main conduit through which the drill string is lowered and through which the drilling mud is circulated from the lower end of the drill string back to the surface. In addition to the

main conduit, there may be provided auxiliary conduits such as, for example, choke and kill lines, pressurized fluid lines, hard pipes, and electrical lines, which extend relatively parallel to the main conduit. These auxiliary conduits and lines are commonly referred to as umbilical elements and/or umbilicals.

There are generally two kinds of water current induced stresses to which elements of a riser system may be exposed. The first kind of stress as mentioned above is caused by vortex-induced alternating forces that vibrate the underwater structure in a direction perpendicular to the direction of the current. These are referred to as vortex-induced vibrations (VIV). When water flows past the structure, vortices are alternately shed from each side of the structure. This produces a fluctuating force on the structure transverse to the current. These vibrations can, depending on the stiffness and the strength of the structure and any welds, lead to unacceptably short fatigue lives. In fact, stresses caused by high current conditions have been known to cause structures such as risers to break apart and fall to the ocean floor. The second type of stress is caused by drag forces which push the structure in the direction of the current due to the structure's resistance to fluid flow. The drag forces may be amplified by vortex induced vibrations of the structure. For instance, a riser pipe that is vibrating due to vortex shedding will disrupt the flow of water around it more so than a stationary riser. This results in greater energy transfer from the current to the riser, and hence more drag.

Many methods have been developed to reduce vibrations of sub sea structures. Some of these methods to reduce vibrations caused by vortex shedding from subsea structures operate by stabilization of the wake. These methods include streamlined fairings, wake splitters and flags. Streamlined or teardrop shaped, fairings that swivel around a structure have been developed that almost eliminate the shedding or vortices. Other conventional methods to reduce vibrations caused by vortex shedding from sub sea structures operate by modifying the boundary layer of the flow around the structure to prevent the correlation of vortex shedding along the length of the structure. Examples of such methods include the use of helical strakes around a structure, or axial rod shrouds and perforated shrouds.

Copending U.S. Patent Application 60/805,136, filed June 19, 2006, having attorney docket number TH1500, discloses a system for producing oil and/or gas, including a subsea structure defining an interior of the system, the structure subject to a water current; a covering exterior to the subsea structure, covering at least a portion of an outside surface of the subsea structure; a vortex induced vibration suppression device exterior to the covering; the covering including a first mechanism and the vortex induced vibration suppression device including a second mechanism, wherein the first mechanism and the second mechanism are adapted to maintain the vortex induced vibration suppression device in a location along a length of the subsea structure. U.S. Patent Application 60/805,136 is herein incorporated by reference in its entirety.

Subsea structures often have umbilical lines, pipes, electrical lines, cables, ropes, lift lines, and/or other smaller lines that run along the length of the structure. When the structure is initially installed these lines are sometimes fitted into insulation or buoyancy modules. However, when other lines are desired and are to be added, for example to run a line on the outside of the structure or after the structure has been installed, the lines need to be held outside of the insulation or buoyancy modules. These additional lines then may interfere with the VIV and/or drag suppression devices that are installed exterior to the insulation or buoyancy modules.

There is a need in the art for improved apparatus and methods for suppressing VIV.

There is a need in the art for apparatus and methods for suppressing VIV that do not suffer from the disadvantages of the prior art.

There is a need in the art for apparatus and methods for providing VIV suppression to a subsea structure comprising additionally installed lines and/or for providing protection to the additionally installed lines.

There is a need for systems and methods of installing VIV suppression devices to a subsea structure with additionally installed lines.

These and other needs will become apparent to those of skill in the art upon review of this specification, including its drawings and claims.

Summary of the Invention

In one aspect, the invention provides a system comprising a subsea structure defining an interior of the system, the structure subject to a water current; a holder exterior to the subsea structure, the holder comprising at least one guide member, the guide member comprising at least one bearing surface; and a vortex induced vibration suppression device exterior to the subsea structure, a portion of the suppression device interfacing with the bearing surface, so that the suppression device is adapted to weathervane about the subsea structure.

In another aspect, the invention provides a method of suppressing vortex induced vibration of a subsea structure, comprising attaching a holder about a circumference of the subsea structure, the holder comprising at least one guide member; installing a vortex induced vibration suppression device about the circumference of the subsea structure; and interfacing at least a portion of the suppression device with the guide member, such that the suppression device can weathervane about the circumference of the subsea structure.

Brief Description of the Figures

Figure 1 illustrates a subsea structure system.

Figure 2a illustrates a subsea structure system.

Figure 2b illustrates a side view of a riser with buoyancy.

Figure 2c illustrates a cross-sectional view of a riser with buoyancy.

Figure 2d illustrates a cross-section view of a fairing holder.

Figure 2e illustrates a cross-sectional view of a riser with buoyancy and a fairing holder.

Figure 2f illustrates a cross-sectional view of a riser with buoyancy, a fairing holder and a fairing.

Figure 2g illustrates a side view of a riser with buoyancy and a fairing holder.

Figure 3a illustrates a cross-sectional side view of a riser and a fairing holder.

Figure 3b illustrates a cross-sectional side view of the riser and fairing holder of Figure 3a with a fairing attached to the fairing holder.

Figure 4a illustrates a cross-sectional side view of a riser and a fairing holder.

Figure 4b illustrates a cross-sectional side view of the riser and fairing holder of Figure 4a with a fairing attached to the fairing holder.

Figure 5a illustrates a cross-sectional side view of a riser and a fairing holder.

Figure 5b illustrates a cross-sectional side view of the riser and fairing holder of Figure 5a with a fairing attached to the fairing holder.

Figure 6a illustrates a cross-sectional side view of a riser and a fairing holder.

Figure 6b illustrates a cross-sectional side view of the riser and fairing holder of Figure 6a with a fairing attached to the fairing holder.

Detailed Description

Referring now to Figure 1 there is illustrated offshore system 100. System 100 includes surface structure 102 near a water surface. Surface structure 102 is connected to subsurface structure 103 adjacent to seafloor 108 by structure 104. In some embodiments, structure 104 may be a tubular such as a riser, an umbilical, or a tendon, or other such structures. The water has current 110, which may cause vortex-induced vibration (VIV) of structure 104. To counter VIV, fairings 114 may be installed along the length of structure 104. Collars 112 are used to keep fairings from moving along the length of structure 104.

Referring now to Figure 2a, system 200 is illustrated. System 200 includes surface structure 202 near the surface of the water. Riser 204 is connected to surface structure 202 at one end and subsurface structure 203 near seafloor 208 at another end. Exterior to riser 204 is buoyancy material 206, such as a foam, which may serve to insulate and/or provide buoyancy to riser 204. Water current 210 may cause VIV on riser 204 and buoyancy material 206.

One or more lines 212 may extend along buoyancy material 206 between surface structure 202 and subsurface structure 203. Lines 212 are added after the installation of buoyancy material 206 such that they are exterior to buoyancy material 206. Fairing holders 216a, 216b, 216c, 216d, 216e, 216f, 216g and 216h are installed to hold additional lines 212 adjacent to buoyancy material 206. Fairings 214a, 214b, 214c and 214d are installed exterior to fairing holders 216a, 216b, 216c, 216d, 216e, 216f, 216g and 216h. Fairing holders 216a, 216b, 216c, 216d, 216e, 216f, 216g and

216h keep fairings 214a, 214b, 214c and 214d at a desired location along subsurface structure 203. In addition, fairing holders 216a, 216b, 216c, 216d, 216e, 216f, 216g and 216h allow fairings 214a, 214b, 214c and 214d to rotate about fairing holders 216a, 216b, 216c, 216d, 216e, 216f, 216g and 216h without interfering with or being tangled with additional lines 212. One or more fairing holders 216a, 216b, 216c, 216d, 216e, 216f, 216g and 216h may be used for each fairing 214a, 214b, 214c and 214d. In one embodiment, as illustrated in Figure 2a, two fairing holders are used for each fairing.

Referring now to Figure 2b, riser 204 is shown with buoyancy material 206 exterior to riser 204. One or more additional lines 212 may run along the length of riser 204 exterior to buoyancy material 206. Fairing holders 216a and 216b are shown secured to riser 204 to hold additional lines 212 adjacent to buoyancy material 206.

Referring now to Figure 2c, a cross-sectional view of the riser and buoyancy material is illustrated. Buoyancy material 206 is positioned external to riser 204. Buoyancy material 206 is illustrated as two sections, 206a and 206b. Sections 206a and 206b may be connected around riser 204. Internal pockets 222a and 222b house lines 220. Representatively, internal pockets 222a and 222b house hydraulic lines, electrical lines, choke and kill lines, or other lines as are needed. Split-half pockets 226a and 226b, defined between sections 206a and 206b, also house lines 220. Lines 220 may further be housed in external pockets 224a and 224b. Although six pockets are illustrated, it is contemplated that any number of internal pockets, split-half pockets and external pockets may be provided.

Referring now to Figure 2d, a cross-sectional view of fairing holder 216 is illustrated. Fairing holder 216 is formed by body 230 having dimensions suitable for positioning fairing holder 216 around riser 204 and buoyancy material 206. Fairing holder 216 may be made of any strong, corrosion resistant material suitable for supporting a fairing, including but not limited to metals and polymers, such as a high density polyethylene or delrin®. In still further embodiments, fairing holder 216 may be made of or include an antifouling material such as copper to prevent marine growth. Fairing holder 216 may be extruded or molded from the desired material.

Body 230 may be divided into two sections 230a and 230b. Sections 230a and 230b may be positioned around opposite sides of buoyancy material 206 and then

connected at their ends to hold body 230 in place. Representatively, sections 230a and 230b may be connected at one end with a hinge 232 and at another end with a bolt or pin 234 inserted through the ends. It is further contemplated that other types and combinations of connectors may be used to connect sections 230a to 230b. In this aspect, body 230 may be opened to position body 230 around buoyancy material 240 and then closed around buoyancy material 204 to secure body to riser 204 and buoyancy material 206. In addition to hinge 232 and pin 234, further securing mechanisms may be used to help secure fairing holder 216 to the underlying riser 204 and buoyancy material 206. For example, as will be discussed more fully in reference to Figures 2g and Figures 3a to 6b, a groove around the underlying tubular member (e.g. buoyancy material 206) and/or a strap may be used to help hold fairing holder 216 in position.

Section 230a may include raised portion 236 positioned around additional lines 212 positioned along an outer surface of buoyancy material 206 to prevent shifting or damage to lines 212 from an overlying fairing 214. Representatively, raised portion 236 may form an arch over lines 212. In this aspect, body 230 may have a slightly elongated circular profile to accommodate underlying lines 212. When positioned around buoyancy material 206, section 230a is positioned over buoyancy material 206 and lines 212 while section 230b is positioned around only buoyancy material 206. Fairing holder 216 may be fixed in place as previously discussed so that lines 212 are held in position adjacent buoyancy material 206 by fairing holder 216.

Bridge 238 may be attached to raised portion 236 to further hold lines 212 in position and protect lines 212 against collapse of fairing holder 216 due to pressure from overlying fairings 214. Representatively, bridge 238 may be positioned between buoyancy material 206 and body 230 and over lines 212. In this aspect, raised portion 236 and bridge 238 provide a larger radial clearance around lines 212. Bridge 238 may be attached to body 230b of fairing holder 216 by pins or bolts 242 through portions of bridge 238 and fairing holder 216. Although pins or bolts 242 are disclosed, it is further contemplated that any connector suitable for securing bridge 238 to fairing holder 216 may be used.

Bridge 238 may include support members 240 to support bridge 238 over lines 212. In some embodiments, bridge 238 and support members 240 may form an “m” shaped structure having one of lines 212 positioned under each arch. Although three support members 240 are illustrated in Figure 2d, it is contemplated that any number of support members 240 may be used. Representatively, where three lines 212 are to be positioned between buoyancy material 206 and bridge 238, four support members 240 may be provided such that two of the support members are positioned between lines 212 and the other two support members are positioned on opposite sides of lines 212. Support members 240 may be of any size and shape suitable for providing a protective bridge over lines 212. Representatively, where lines 212 have a 2 inch diameter, support members 240 may have a length such that a highest point of bridge 238 is more than 2 inches from the surface of buoyancy material 206. In this aspect, bridge 238 may be positioned over lines 212. Bridge 238 may have a substantially rectangular or square profile. Bridge 238 may be made of any material capable of withstanding pressure from overlying fairings. Representatively, bridge 238 may be made of a metal material such as steel or copper.

In some embodiments, bridge 238 may have a resilient property such that it can accommodate changes in the size of the pocket between fairing holder 216 and buoyancy material 206. It is contemplated that forces applied by fairing holder 216 and hydrostatic changes in the size of buoyancy material 206 may reduce or enlarge the size of the pocket formed between body 230 and buoyancy material 206. In this aspect, bridge 238 may have a shape or be made of a material having resilient characteristics that can accommodate such changes. For example, support members 240 may be made of soft plastics, urethane, or other synthetic materials.

Referring now to Figure 2e, a cross-sectional view of a riser with buoyancy material and a fairing holder is shown. Buoyancy material 206 is positioned around riser 204 and fairing holder 216 is positioned around buoyancy material 206 as previously discussed. Although not illustrated in Figure 2e, in some embodiments a groove may be formed around buoyancy material 206 (see, for example, Figure 2g. Fairing holder 216 may be positioned within the groove to help secure fairing holder 216 in place.

As illustrated in Figure 2e, bridge 238 of fairing holder 230 is positioned over additional lines 212a and 212b along an outer surface of buoyancy material 206. Although typically buoyancy material 206 has a circular profile, in some embodiments, buoyancy material 206 includes a flattened portion 244 along which lines 212a and 212b are positioned. Flattened portion 244 allows overlying fairing holder 216 to maintain the smallest diameter possible while still allowing fairing holder 216 to accommodate additional lines 212a and 212b. Although Figure 2e illustrates an embodiment of buoyancy material 206 having one flattened portion 244, it is further contemplated that buoyancy material 206 may have more than one flattened portion to accommodate additional lines 212.

Referring now to Figure 2f, fairing 214 is shown attached exterior to fairing holder 216. Fairing 214 may be formed of two or more sections hinged together. In this aspect, to attach fairing 214 around buoyancy material 206 and fairing holder 216, fairing 214 may be opened and then closed around buoyancy material 206 and fairing holder 216. When sections of fairing 214 are aligned, screws 244 may be attached to inner member 246 to hold the sections together.

Referring now to Figure 2g, riser 204 and buoyancy material 206 are illustrated with grooves 248a and 248b spaced along the length of riser 204. Grooves 248a and 248b may be formed in buoyancy material 206. Fairing holders 216 may be placed in grooves 248a and 248b to maintain fairing holders 216a and 216b, respectively, at a desired location along the length of riser 204 and buoyancy material 206. In addition to grooves 248a and 248b, an attachment mechanism may be used to secure fairing holders 216a and 216b to riser 204. Representatively, as will be discussed more fully below, straps may be tightened around fairing holders 216a and 216b to further secure fairing holders 216a and 216b to riser 204.

Figure 3a illustrates a cross-sectional side view of a riser and a fairing holder. Buoyancy material 306 is shown positioned around riser 304. Fairing holder 316 may be positioned within a groove around buoyancy material 306 as previously described and secured to buoyancy material 306 by attachment mechanism 324. In some embodiments, attachment mechanism 324 may be a strap or band positioned around fairing holder 316. The strap or band 324 may be made of any suitable synthetic

material. In other embodiments, band 324 may be made of a metal or metal alloy which is resistant to extreme temperatures and corrosion (e.g. Inconel®, a nickel-based superalloy). Although one attachment mechanism 324 is illustrated it is contemplated that any number of attachment mechanisms may be used.

Fairing holder 316 may include guide members 320 and 322 extending from body 330 of fairing holder 316. Guide members 320 and 322 serve to maintain placement of a vortex suppression device (for example a fairing) positioned along buoyancy material 306. Although two guide members 320 and 322 are disclosed, it is further contemplated that a single guide member may be used. Guide members 320 and 322 may be substantially straight and are positioned perpendicular to body 330. In this aspect, guide members 320 and 322 provide a supporting ledge for an adjacent fairing. It is contemplated, however, that guide members 320 and 322 may be of any size and shape suitable for providing a supporting ledge for fairing 314 as illustrated in Figure 3b and discussed more fully below. Guide members 320, 322 and body 330 may be made of the same or different material. Representatively, guide members 320, 322 and/or body 330 may be made of an antifouling material such as copper. In still further embodiments, guide members 320, 322 and body 330 may be made of a high density polyethylene or delrin®.

Figure 3b illustrates a cross-sectional side view of the riser and fairing holder of Figure 3a with a fairing attached to the fairing holder. As shown in Figure 3b, fairing 314 is positioned between fairing holders 316a and 316b such that guide member 322a of fairing holder 316a and guide member 320b of fairing holder 316b are adjacent opposite ends of fairing 314. In this aspect, fairing 314 is held in position along a portion of buoyancy material 306 between fairing holders 316a and 316b. Bands 324a and 324b are provided to secure fairing holders 316a and 316b, respectively, to underlying buoyancy material 306. Although only fairing 314 is shown, it is contemplated that additional fairings may be positioned on opposite sides of fairing holders 316a and 316b to that of fairing 314 and held in place along buoyancy material 306 using guide member 320a and 322b.

In some embodiments, a portion of body 330a and 330b is positioned between fairing 314 and buoyancy material 306 to provide a space between fairing 314 and

buoyancy material 306 which prevents fairing 314 from contacting the underlying buoyancy material 306. Although not shown, it is contemplated that additional lines (e.g. lines 212) may be positioned between buoyancy material 306 and fairing holders 316a and 316b as previously discussed. In this aspect, fairing 314 is free to rotate or weather vane about buoyancy material 306 without damaging the underlying lines.

Figure 4a illustrates a cross-sectional side view of a riser and a fairing holder. Buoyancy material 406 is shown positioned around riser 404. Fairing holder 416 may be secured to buoyancy material 406 by attachment mechanism 424. In some embodiments, attachment mechanism 424 may be a strap or band positioned around fairing holder 416 as previously discussed. Although one attachment mechanism 424 is illustrated, it is contemplated that any number of attachment mechanisms may be used.

Guide members 420 and 422 for maintaining placement of a vortex suppression device (e.g. a fairing) along buoyancy material 406 may extend from body 430 of fairing holder 416. Similar to the guide members described in reference to Figures 3a and 3b, guide members 420 and 422 are perpendicular to body 330. In this embodiment, however, guide members 420 and 422 are substantially "L" shaped with their free ends positioned away from one another as shown in Figure 4a. In this aspect, channels 421 and 423 are formed between each of guide members 420, 422 and body 430, respectively. As will be described in more detail in reference to Figure 4b, ends of fairing 414 are inserted within channels 421 and 423 to hold fairing 414 in position along buoyancy material 406. Openings to channels 421 and 423 may be on opposite sides of fairing holder 416. Guide members 420 and 422 may be made of the same or different material (e.g. copper) than body 430.

Referring to Figure 4b, Figure 4b illustrates a cross-sectional side view of the riser and fairing holder of Figure 4a with a fairing attached to the fairing holder. As shown in Figure 4b, fairing 414 is positioned between fairing holders 416a and 416b. One end of fairing 414 is positioned within channel 423a formed between guide member 422a and body 430a of fairing holder 416a and another end of fairing 414 is positioned within channel 421b formed between guide member 420b and body 430b of fairing holder 416b. In this aspect, fairing 414 is held in position along a portion of buoyancy material 406 between fairing holders 416a and 416b. Although only fairing 414 is

shown, it is contemplated that additional fairings may be positioned on opposite sides of fairing holders 416a and 416b to that of fairing 414 and held in place along buoyancy material 406 using guide member 420a and 422b.

In some embodiments, a portion of body 430a and 430b is positioned between fairing 414 and buoyancy material 406 to provide a space between fairing 414 and buoyancy material 406 which prevents fairing 414 from contacting the underlying buoyancy material 406. Although not shown, it is contemplated that lines (e.g. umbilicals) may be positioned between buoyancy material 406 and fairing holder 416a and 416b as previously discussed. In this aspect, fairing 414 is free to rotate or weather vane about buoyancy material 406 without damaging the underlying lines.

Figure 5a illustrates a cross-sectional side view of a riser and a fairing holder. Buoyancy material 506 is shown positioned around riser 504. Fairing holder 516 may be secured to buoyancy material 506 by attachment mechanism 524. In some embodiments, attachment mechanism 524 may be a strap or band positioned around fairing holder 516 as previously discussed. Although one attachment mechanism 524 is illustrated, it is contemplated that any number of attachment mechanisms may be used.

Guide members 520 and 522 for maintaining placement of a vortex suppression device (e.g. a fairing) along buoyancy material 506 may extend from body 530. Guide members 520 and 522 may be substantially the same as the guide members described in reference to Figures 3a and 3b.

Figure 5b illustrates a cross-sectional side view of the riser and fairing holder of Figure 5a with a fairing attached to the fairing holder. Fairing 514 may be secured to fairing holder 516 using ring 534 and connector 532. Ring 534 is positioned around fairing holder 516 and within channel 538 formed between guide members 520 and 522. Alternatively, ring 534 may be positioned outside of fairing holder 516 (i.e. between fairing 514 and fairing holder 516). Representatively, ring 534 may be placed around buoyancy material 506 directly or within a housing forming a channel around a portion of buoyancy material 506 adjacent fairing holder 516. The channel may be made of the same or different material (e.g. copper) as fairing holder 516. Fairing 514 may then be attached to ring 534 via connector 532.

Ring 534 may be a complete or partial ring. In embodiments where ring 534 is a partial ring, ring 534 may be made of ring sections attached to an end of each connector and positioned within channel 538 between guide members 520 and 522. In some embodiments, ledges may be formed along ends of guide members 520 and 522 to retain ring 534 within channel 538. Representatively, guide members 520 and 522 may have a substantially "L" shape similar to the support members of Figure 4a except with the free ends facing one another to form the ledges.

In embodiments where ring 534 is a complete ring, ring 534 may include two sections which may be connected together by any suitable attachment mechanism. Representatively, sections of ring 534 may be connected by a hinge and/or bolt. In this aspect, once fairing holder 516 is positioned around buoyancy material 506 as previously discussed, each section of ring 534 may be positioned around fairing holder 516 and then bolted together at its ends. It is further contemplated that in some embodiments, ring 534 may be attached to fairing holder 516 prior to assembly of fairing holder 516 around buoyancy material 506. Representatively, ring 534 may be temporarily attached (e.g. pinned) to fairing holder 516 and then released at the water surface or below the surface by a diver or remotely operated vehicle (ROV) once fairing holder 516 is positioned around buoyancy material 506. It is further contemplated that ring 534 may be used for retrofitting of devices and have a latch on ring 534 to position ring 534 within fairing holder 516. It is further contemplated that ring 534 may be installed in separate pieces attached to fairing holder 516 and fairing 514. Once installed, ring 534 may be released from fairing holder 516 as previously discussed.

Ring 534 may have any size and shape suitable for rotation around an underlying fairing holder 516. It is contemplated that in some embodiments, for example, when fairing holder 516 includes a raised portion as previously described to accommodate additional lines external to buoyancy material 506, the underlying fairing holder 516 may not have a circular profile. In this aspect, ring 534 may have a circular profile of a large enough diameter to rotate around the elongated fairing holder 516 thereby providing a circular surface for attachment or rotation of fairing 514 around riser 504. For example, in some embodiments, fairing holder 516 may have a nine inch outer diameter (taking

into account the raised portion) and ring 534 may have an inner diameter greater than nine inches.

Ring 534 may be made of an antifouling material that requires minimal cleaning and will not easily collect marine growth that may impede rotation of ring 534 and in turn fairing 514. Representatively, ring 534 may be made of copper or a copper alloy. Ring 534 may also be coated with an anti-fouling or a fouling release coating or paint.

Fairing 514 may be attached to ring 534 with connectors 532 and 536. Since fairing 514 is secured to fairing holder 516, fairing holders do not need to be positioned at each end to hold the fairing in position along buoyancy material 506 and instead a single fairing holder 516 may be used. Connectors 532 and 536 may be attached at one end to fairing 514 and extend into channel 538 between guide members 520 and 522 to attach at another end to ring 534 as shown. In this aspect, connectors 532 and 536 may have any shape and size suitable for extending over a guide member adjacent the end of fairing 514 and into channel 538 to attach to ring 534. Representatively, connector 532 may have a substantially "L" when attached to fairing 514 a distance from buoyancy material 506 which is greater than a length of guide members 520 and 522. Connector 536 may have a substantially "U" shape when attached to fairing 514 a distance from buoyancy material 506 which is less than or equal to a length of guide member 520 so that it may extend up and over guide member 520. Connectors 532 and 536 may be attached to fairing 514 and ring 534 using any suitable attachment mechanism. Representatively, connectors 532 and 536 may be bolted or pinned to fairing 514 and ring 534.

One or more of connectors 532 and 536 may be used to attach fairing 514 to ring 534. Representatively, connector 532 may be attached to one end of fairing 514 and another connector may be attached to an opposite end of fairing 514 (not shown). In this aspect, each end of fairing 514 may be attached to a ring 534 within fairing holders at each end of fairing 514. In still further embodiments, two connectors 532 and 536 may be attached to one or both ends of fairing 514 such that two or four connectors may be used. Representatively, connector 532 may be attached to a tail of fairing 514 and connector 536 may be attached to a nose of fairing 514. Any number of additional

connectors 532 needed to securely attach fairing 514 to ring 534 may be added about the circumference of the fairing.

Similar to ring 534, connectors 532 and 536 may be made of an antifouling material, including, but not limited to, copper and copper alloys. It is further contemplated that in some embodiments ring 534 may be made of a flexible material. Representative flexible materials for connectors 532 and 536 may include, but are not limited to plastics, rubbers such as urethane and neoprene, and other synthetics. In this embodiment, mechanical stops (not shown) may be provided to limit a range of ring 534 rotation so that connectors 532 and 534 do not become tangled. For example, knobs may extend from an outer surface of body 530 which catch on knobs spaced around an inner surface of ring 534 so that a rotation of ring 534 is limited to a distance between adjacent knobs of body 530. Alternatively, ring 534 may be omitted and connector 532 attached directly to fairing holder 516. In this aspect, fairing 516 is allowed only limited rotation about fairing holder 516.

Figure 6a illustrates a cross-sectional side view of a riser and a fairing holder. Buoyancy material 606 is shown positioned around riser 604. Fairing holder 616 may be secured to buoyancy material 606 by attachment mechanism 624. In some embodiments, attachment mechanism 624 may be a strap or band positioned around fairing holder 616 as previously discussed. Although one attachment mechanism 624 is illustrated it is contemplated that any number of attachment mechanisms may be used.

Guide members 620 and 622 for maintaining placement of a vortex suppression device (e.g. a fairing) along buoyancy material 606 may extend from body 630. Guide members 620 and 622 may be substantially the same as the guide members described in reference to Figures 5a and 5b in that they are perpendicular to body 630, however, in this embodiment, guide members 620 and 622 may be substantially "L" shaped. The free ends of the "L" shaped guide members 620 and 622 may face one another to form channel 621 as shown in Figure 6a.

Insert 634 may be positioned within channel 621. Similar to ring 534 of Figures 5a and 5b, insert 634 may serve as an attachment point for fairing 614 and secure fairing 614 to fairing holder 616 at a desired position along the underlying riser 604. Insert 634 may include base 640 and knob 642 extending from base 640. Base 640 is

retained within channel 621 formed by guide members 620. Base 640 is positioned within channel 621. Knob 642 projects through the opening of channel 621 and beyond guide members 620 and 622 to provide an attachment point for fairing 614. In some embodiments, opening 644 may be formed in knob 642 to facilitate attachment of fairing 614. Representatively, a bolt or pin may be inserted through fairing 614 and opening 644 in insert 634 to attach fairing 614 to insert 634. Insert 634 may slide around fairing holder 616 thereby allowing for weathervaning of fairing 614 attached thereto.

One or more of insert 634 may be positioned within channel 621 of fairing holder 616. Similar to ring 534 described in reference to Figures 5a and 5b, insert may be made of an antifouling material including, but not limited to, copper. In some embodiments, insert 634 may be attached to fairing holder 616 prior to positioning of fairing holder 616 around buoyancy material 606. Representatively, prior to closing each half of fairing holder 616 around buoyancy material 606, insert 634 may be inserted within an open end of channel 621 of fairing holder 616.

Figure 6b illustrates a cross-sectional side view of the riser and fairing holder of Figure 6a with a fairing attached to the fairing holder. Fairing 614 may be attached to fairing holders 616a, 616b using inserts 634a, 634b and connectors 632, 636. Insert 634a is positioned within channel 621a formed between guide members 620a and 622a. Insert 634b is positioned within channel 621b formed between guide members 620b and 622b.

Fairing 614 may be connected to inserts 634a and 634b at each end with connectors 632 and 636, respectively. Connectors 632 and 636 may be secured to ends of fairing 614 or knobs 634a and 634b using any suitable securing mechanism, including, but not limited to, screws, pins or bolts. For example, openings 644a and 644b may be formed in knobs 634a and 634b, respectively, to receive a bolt, screw or pin extending from fairing 614. Connectors 632 and 636 may have any shape or size suitable for extending from fairing 614 to inserts 634a and 634b, respectively. Representatively, connectors 632 and 636 may have a substantially "L" shape as shown in Figure 5b.

One or more of connectors 632 and 636 may be used to attach fairing 614 to inserts 634a and 634b. Representatively, two connectors 632 and 636 at each end of

fairing 614 as shown may be used. Although two connectors are illustrated, it is contemplated that any number of additional connectors needed to securely attach fairing 614 to inserts 634a and 636b may be used.

Similar to inserts 634a and 636b, connectors 632 and 636 may be made of an antifouling material, including, but not limited to, copper.

Fairings may be replaced with strakes, shrouds, wake splitters, tail fairings, buoyancy modules, or other devices as are known in the art. Suitable sleeves, suitable collars, and suitable devices to install exterior to structures, and methods of their installation are disclosed in U.S. Patent Application Number 10/839,781, having attorney docket number TH1433; U.S. Patent Application Number 11/400,365, having attorney docket number TH0541; U.S. Patent Application Number 11/419,964, having attorney docket number TH2508; U.S. Patent Application Number 11/420,838, having attorney docket number TH2876; U.S. Patent Application Number 60/781,846 having attorney docket number TH2969; U.S. Patent Application Number 60/805,136, having attorney docket number TH1500; U.S. Patent Application Number 60/866,968, having attorney docket number TH3112; U.S. Patent Application Number 60/866,972, having attorney docket number TH3190; U.S. Patent Number 5,410,979; U.S. Patent Number 5,410,979; U.S. Patent Number 5,421,413; U.S. Patent Number 6,179,524; U.S. Patent Number 6,223,672; U.S. Patent Number 6,561,734; U.S. Patent Number 6,565,287; U.S. Patent Number 6,571,878; U.S. Patent Number 6,685,394; U.S. Patent Number 6,702,026; U.S. Patent Number 7,017,666; and U.S. Patent Number 7,070,361, which are herein incorporated by reference in their entirety.

Suitable methods for installing fairings, collars, and other devices to install exterior to structures, are disclosed in U.S. Patent Application Number 10/784,536, having attorney docket number TH1853.04; U.S. Patent Application Number 10/848,547, having attorney docket number TH2463; U.S. Patent Application Number 11/596,437, having attorney docket number TH2900; U.S. Patent Application Number 11/468,690, having attorney docket number TH2926; U.S. Patent Application Number 11/612,203, having attorney docket number TH2875; U.S. Patent Application Number 60/806,882, having attorney docket number TH2879; U.S. Patent Application Number 60/826,553, having attorney docket number TH2842; U.S. Patent Number 6,695,539;

U.S. Patent Number 6,928,709; and U.S. Patent Number 6,994,492; which are herein incorporated by reference in their entirety.

The fairing holder and/or fairings may be installed on the tubular member (e.g. buoyancy material and riser) before or after the tubular member is placed in a body of water.

The fairing holders, fairings and/or other devices exterior to the structure may have a clamshell configuration, and may be hinged with a closing mechanism opposite the hinge, for example a mechanism that can be operated with an ROV.

Fairings may be provided with copper plates on their ends to allow them to weathervane with adjacent fairings or collars.

Fairings may be partially manufactured from copper.

While VIV suppression devices such as fairings are described, it is contemplated that the embodiments described herein may further be used in connection with special anodes, VIV enhancement devices or rotating devices.

Illustrative Embodiments:

In one embodiment, there is disclosed a system comprising a subsea structure defining an interior of the system, the structure subject to a water current; a holder exterior to the subsea structure, the holder comprising at least one guide member, the guide member comprising at least one bearing surface; and a vortex induced vibration suppression device exterior to the subsea structure, a portion of the suppression device interfacing with the bearing surface, so that the suppression device is adapted to weathervane about the subsea structure. In some embodiments, the subsea structure is selected from an umbilical, a riser, and a tendon. In some embodiments, the system also includes a covering exterior to the subsea structure and interior to the holder, the covering comprising foam adapted to provide buoyancy and/or thermal insulation to the subsea structure. In some embodiments, the vortex induced vibration suppression device comprises a fairing. In some embodiments, the system also includes at least one line exterior to the subsea structure, the at least one line within a covering. In some embodiments, the holder comprises a top guide member and a bottom guide member. In some embodiments, the top guide member comprises a bearing surface interfacing

with a suppression device above the holder. In some embodiments, the bottom guide member comprises a bearing surface interfacing with a suppression device below the holder. In some embodiments, the system also includes a covering exterior to the subsea structure and interior to the holder, wherein the covering comprises one or more circumferential grooves, the holder within the groove. In some embodiments, the system also includes an attachment mechanism adapted to maintain the holder at a desired location along a length of the subsea structure. In some embodiments, the holder comprises one or more channels adapted to allow the vortex induced vibration suppression device to rotate about the structure. In some embodiments, the vortex induced vibration suppression device comprises a ring adapted to fit within a channel. In some embodiments, the vortex induced vibration suppression device comprises an insert adapted to fit within a channel. In some embodiments, the holder is connected to the structure with one or more of the following: bands, screws, bolts, and glue.

In one embodiment, there is disclosed a method of suppressing vortex induced vibration of a subsea structure, comprising attaching a holder about a circumference of the subsea structure, the holder comprising at least one guide member; installing a vortex induced vibration suppression device about the circumference of the subsea structure; and interfacing at least a portion of the suppression device with the guide member, such that the suppression device can weathervane about the circumference of the subsea structure.

Those of skill in the art will appreciate that many modifications and variations are possible in terms of the disclosed embodiments, configurations, materials and methods without departing from their spirit and scope. Accordingly, the scope of the claims appended hereafter and their functional equivalents should not be limited by particular embodiments described and illustrated herein, as these are merely exemplary in nature.

C L A I M S

1. A system comprising:
a subsea structure defining an interior of the system, the structure subject to a water current;
a holder exterior to the subsea structure, the holder comprising at least one guide member, the guide member comprising at least one bearing surface; and
a vortex induced vibration suppression device exterior to the subsea structure, a portion of the suppression device interfacing with the bearing surface, so that the suppression device is adapted to weathervane about the subsea structure.
2. The system of claim 1, wherein the subsea structure is selected from an umbilical, a riser, and a tendon.
3. The system of one or more of claims 1-2, further comprising a covering exterior to the subsea structure and interior to the holder, the covering comprising foam adapted to provide buoyancy and/or thermal insulation to the subsea structure.
4. The system of one or more of claims 1-3, wherein the vortex induced vibration suppression device comprises a fairing.
5. The system of one or more of claims 1-4, further comprising at least one line exterior to the subsea structure, the at least one line within a covering.
6. The system of one or more of claims 1-5, wherein the holder comprises a top guide member and a bottom guide member.
7. The system of claim 6, wherein the top guide member comprises a bearing surface interfacing with a suppression device above the holder.

8. The system of one or more of claims 6-7, wherein the bottom guide member comprises a bearing surface interfacing with a suppression device below the holder.
9. The system of one or more of claims 1-8, further comprising a covering exterior to the subsea structure and interior to the holder, wherein the covering comprises one or more circumferential grooves, the holder within the groove.
10. The system of one or more of claims 1-9, further comprising an attachment mechanism adapted to maintain the holder at a desired location along a length of the subsea structure.
11. The system of one or more of claims 1-10, wherein the holder comprises one or more channels adapted to allow the vortex induced vibration suppression device to rotate about the structure.
12. The system of claim 11, wherein the vortex induced vibration suppression device comprises a ring adapted to fit within a channel.
13. The system of one or more of claims 11-12, wherein the vortex induced vibration suppression device comprises an insert adapted to fit within a channel.
14. The system of one or more of claims 1-13, wherein the holder is connected to the structure with one or more of the following: bands, screws, bolts, and glue.
15. A method of suppressing vortex induced vibration of a subsea structure, comprising:
 - attaching a holder about a circumference of the subsea structure, the holder comprising at least one guide member;
 - installing a vortex induced vibration suppression device about the circumference of the subsea structure; and

interfacing at least a portion of the suppression device with the guide member, such that the suppression device can weathervane about the circumference of the subsea structure.

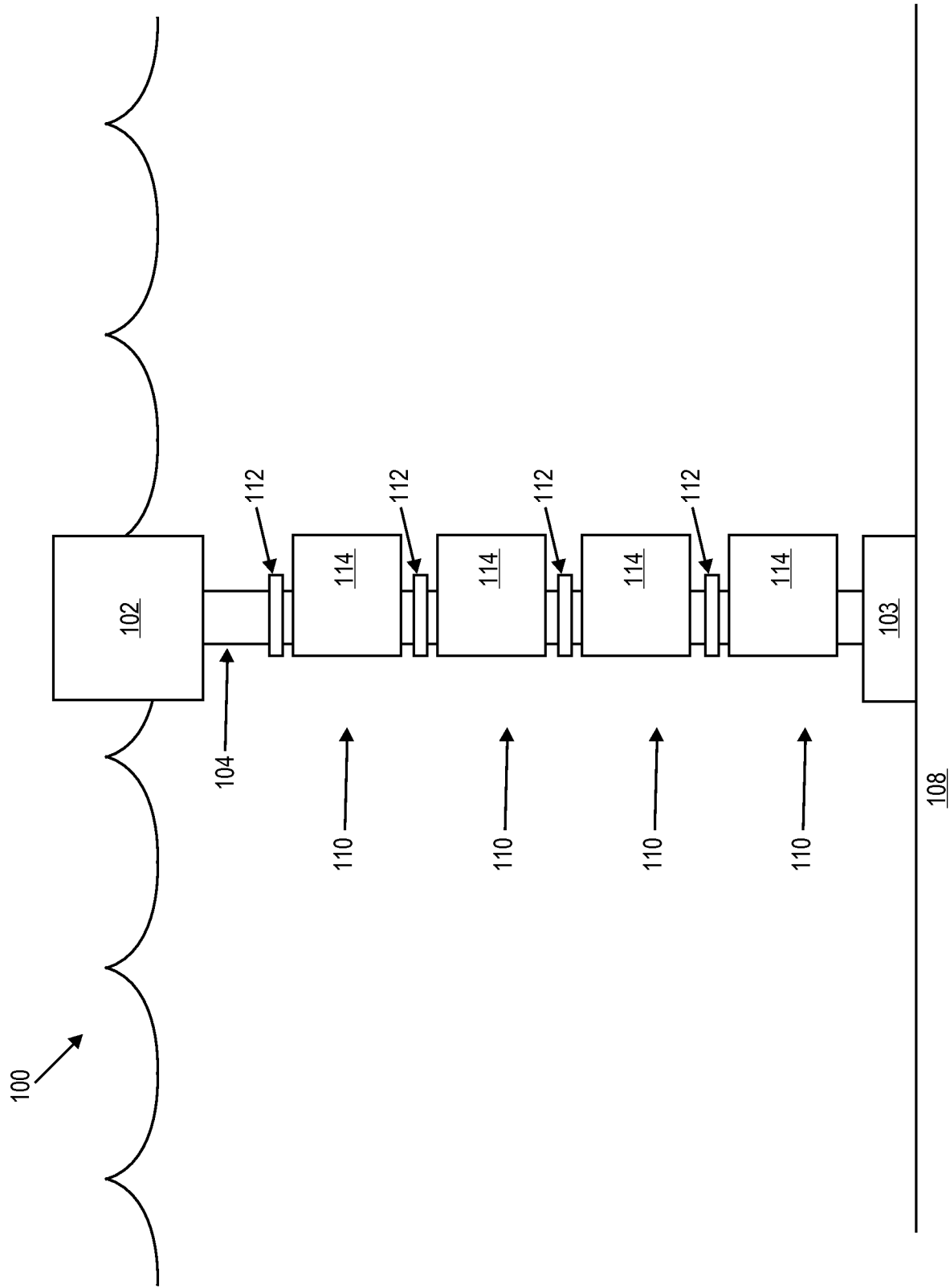


FIG. 1

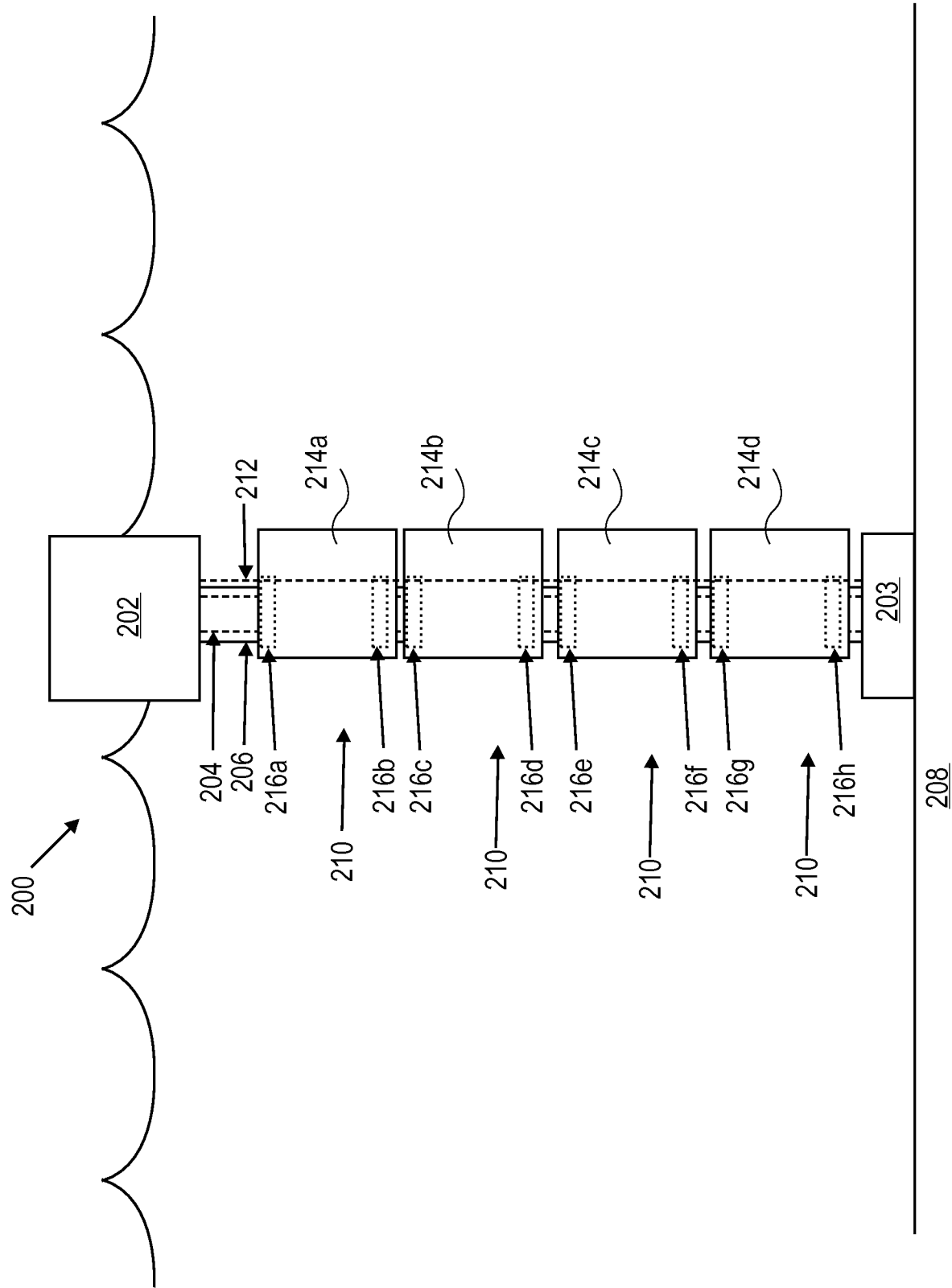


FIG. 2a

3/12

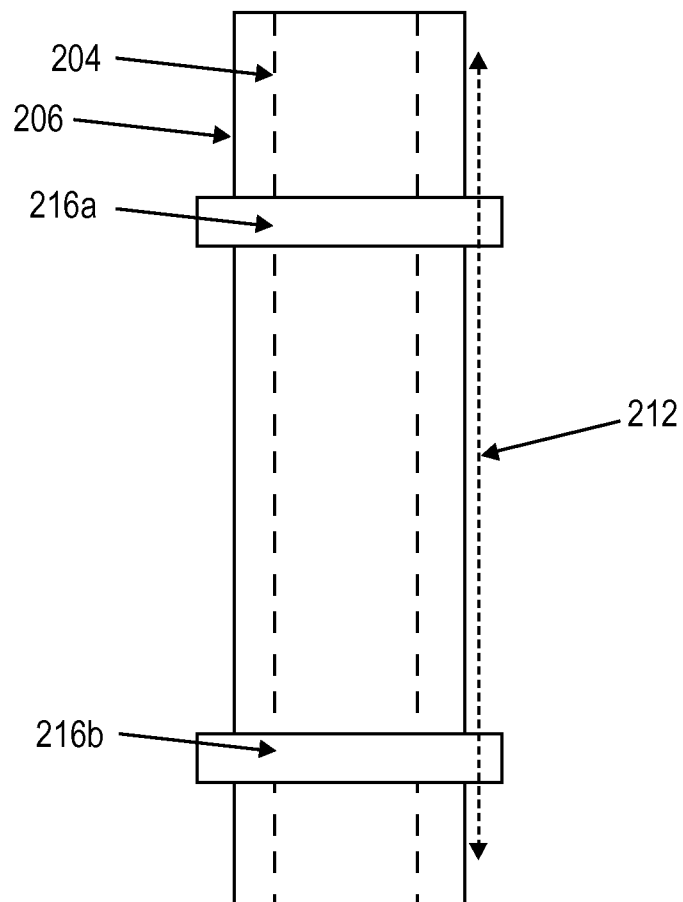


FIG. 2b

4/12

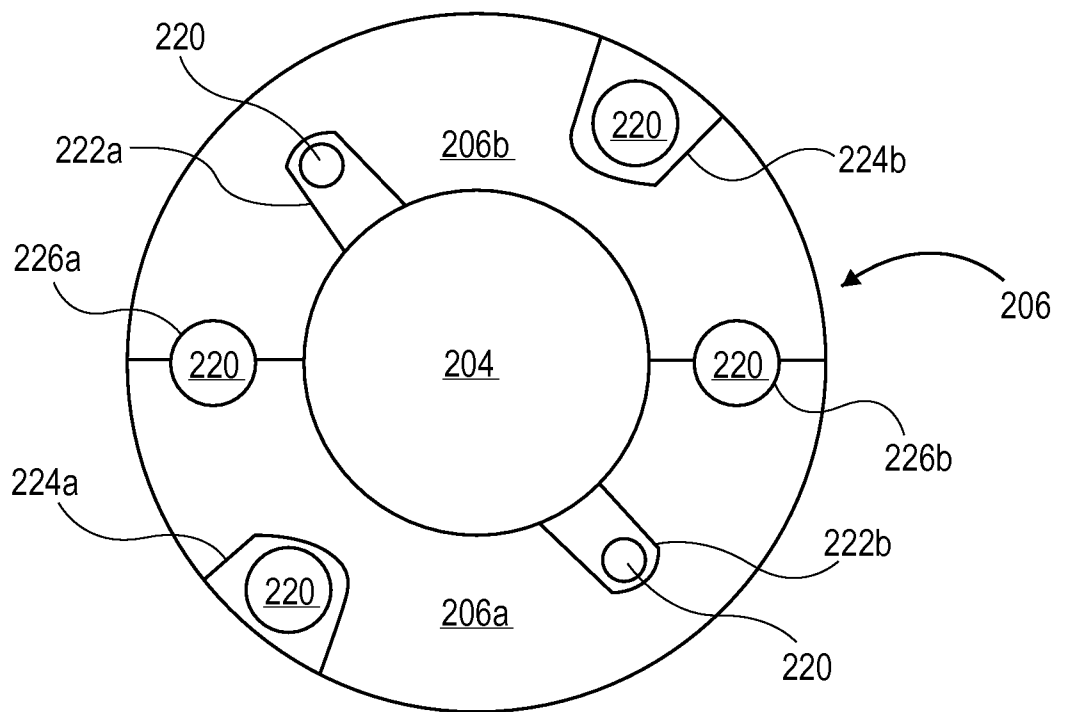


FIG. 2c

5/12

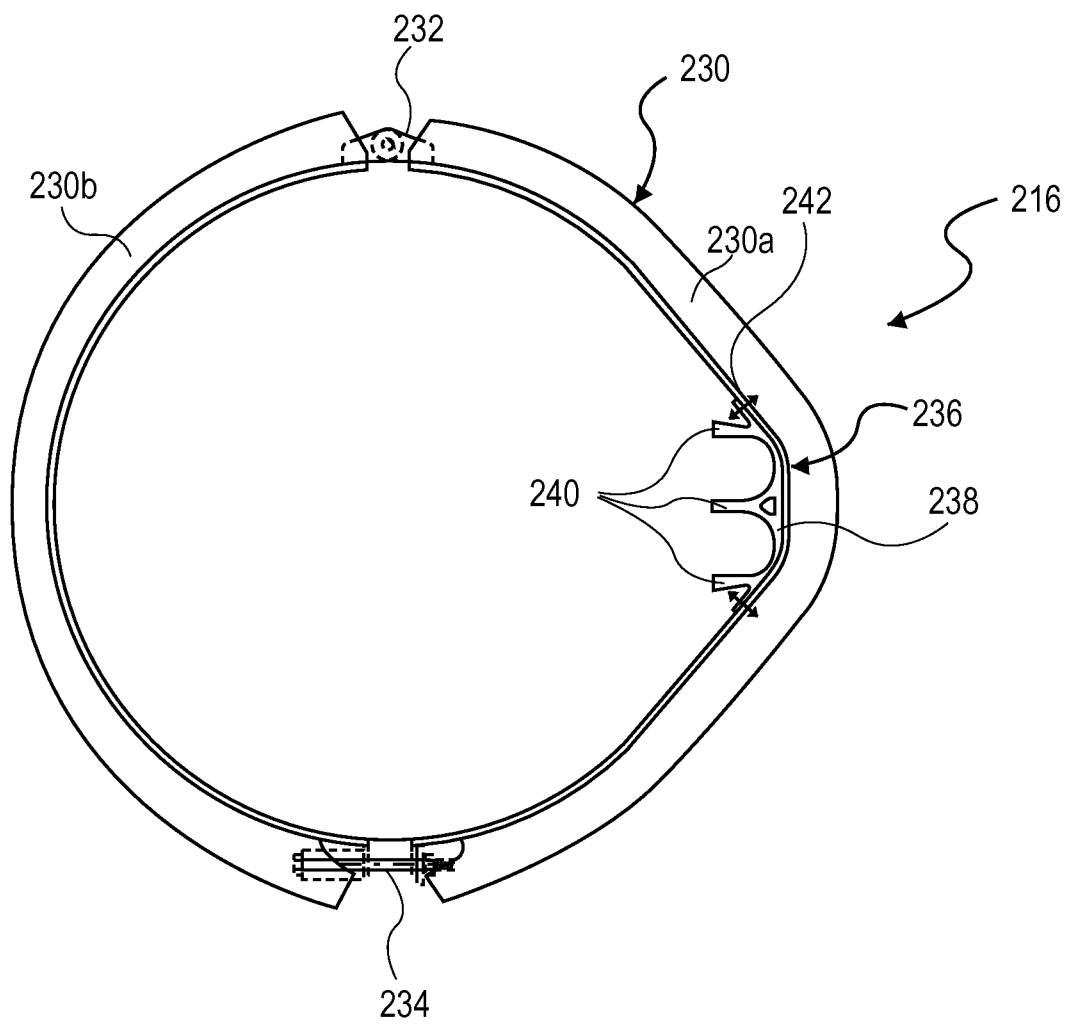
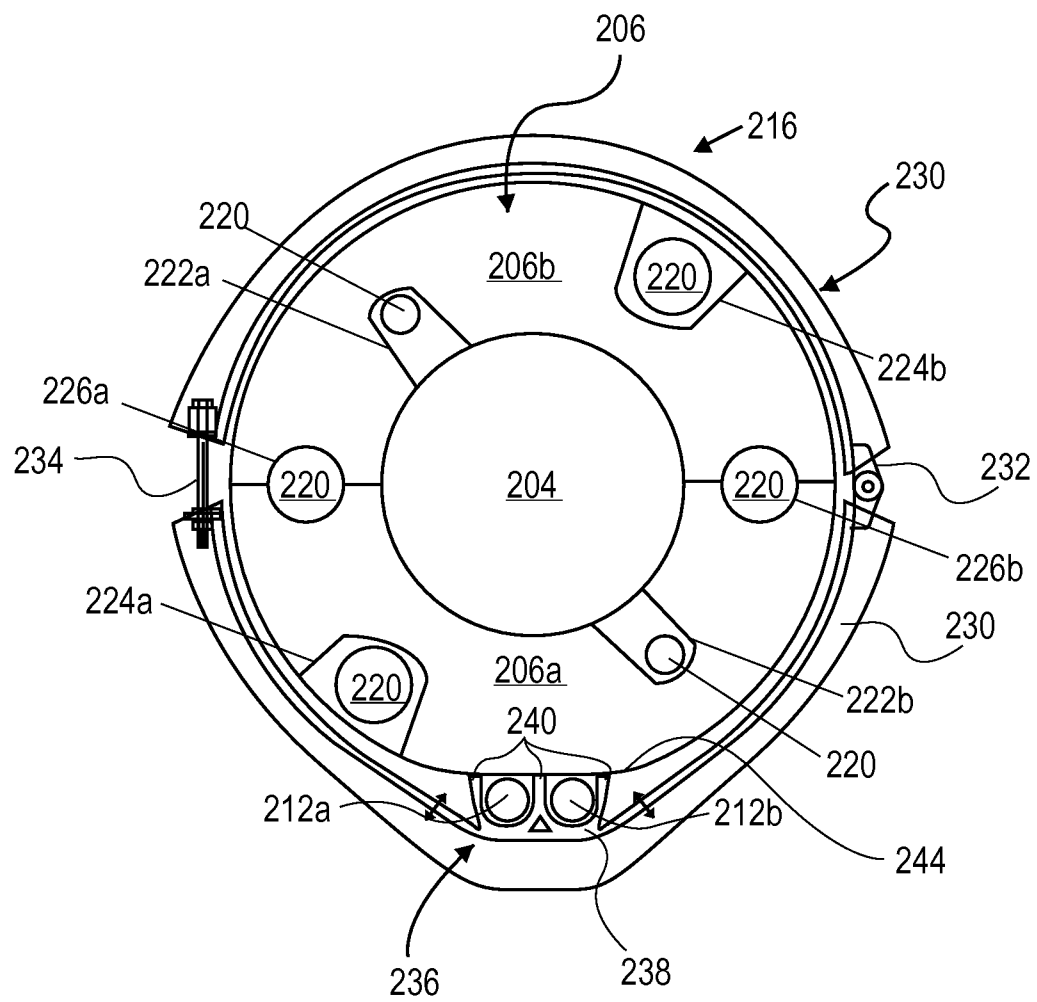


FIG. 2d

6/12

**FIG. 2e**

7/12

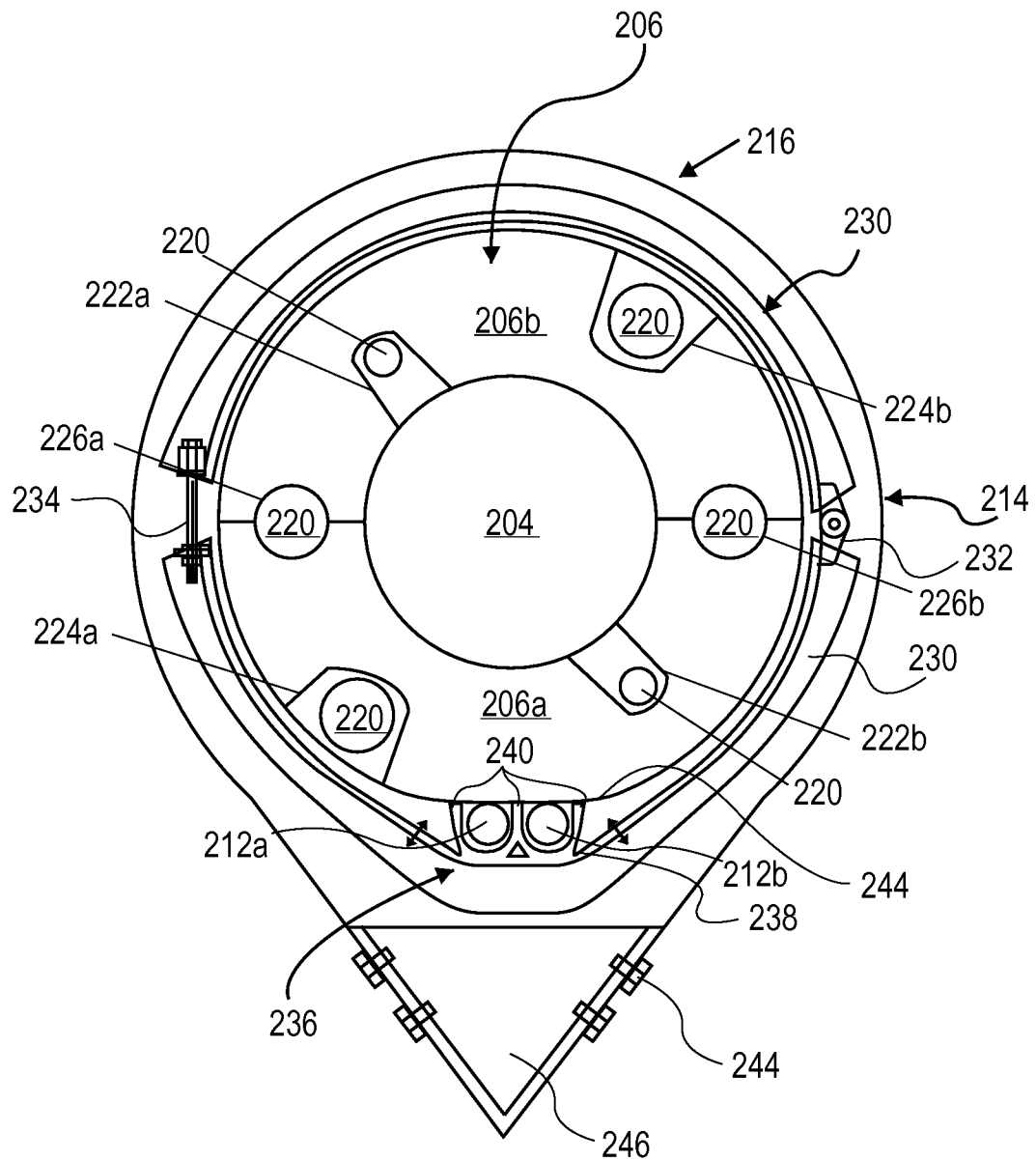


FIG. 2f

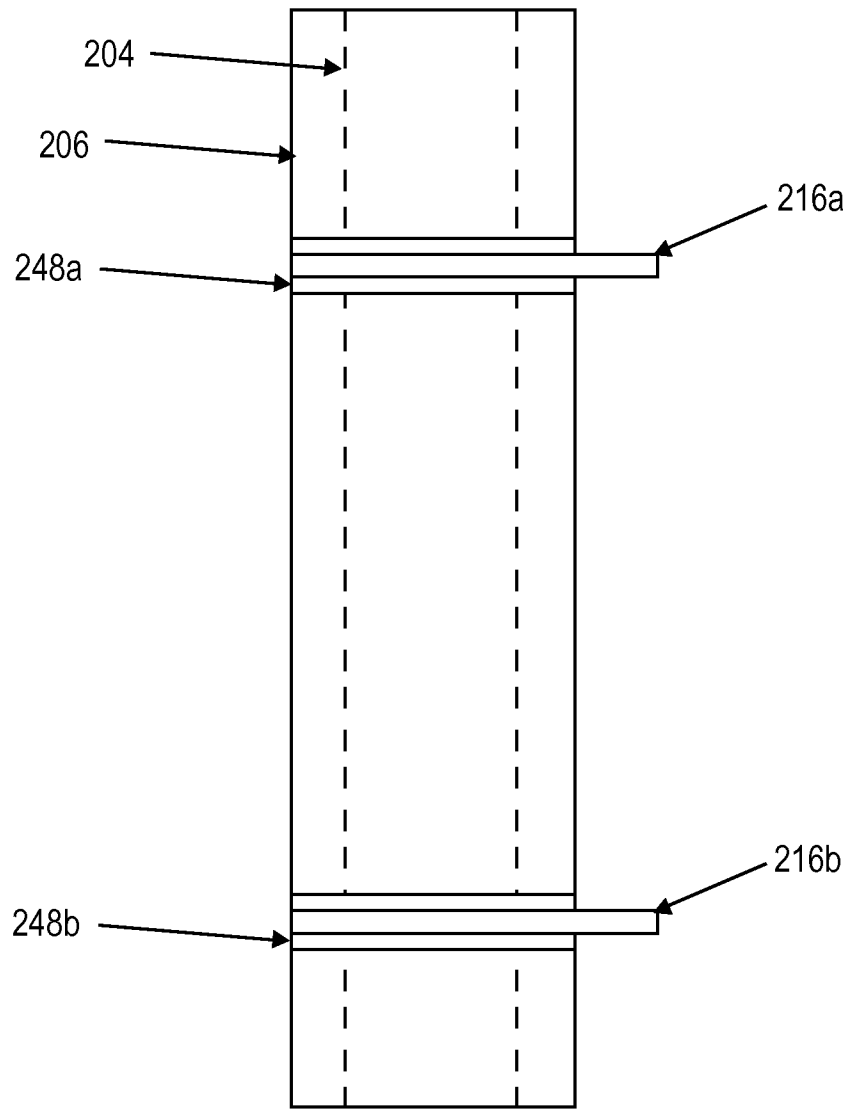


FIG. 2g

9/12

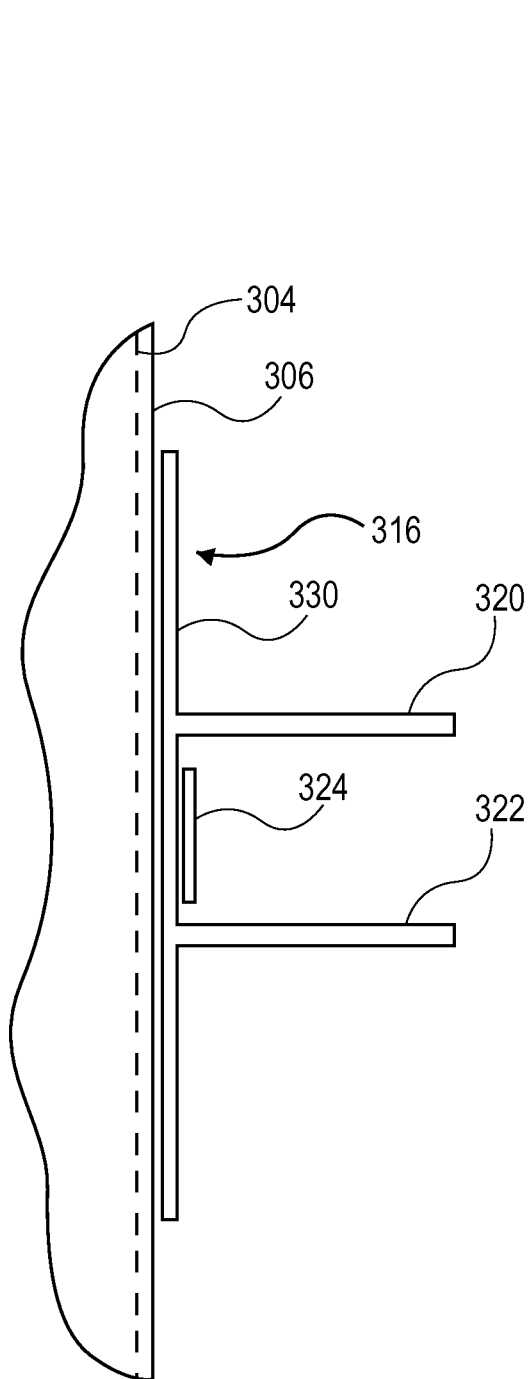


FIG. 3a

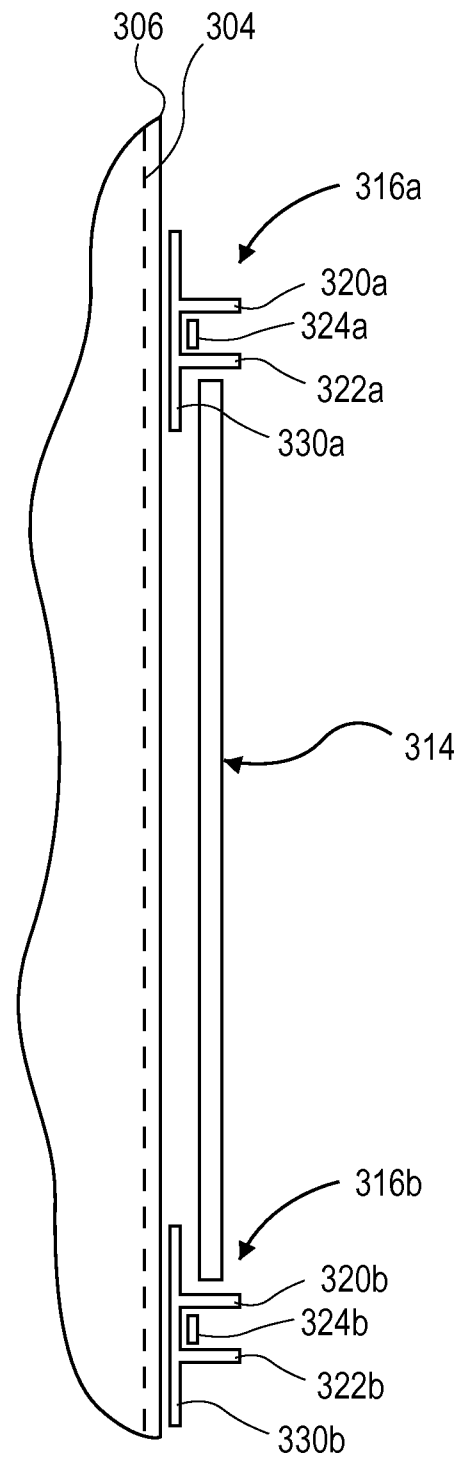


FIG. 3b

10/12

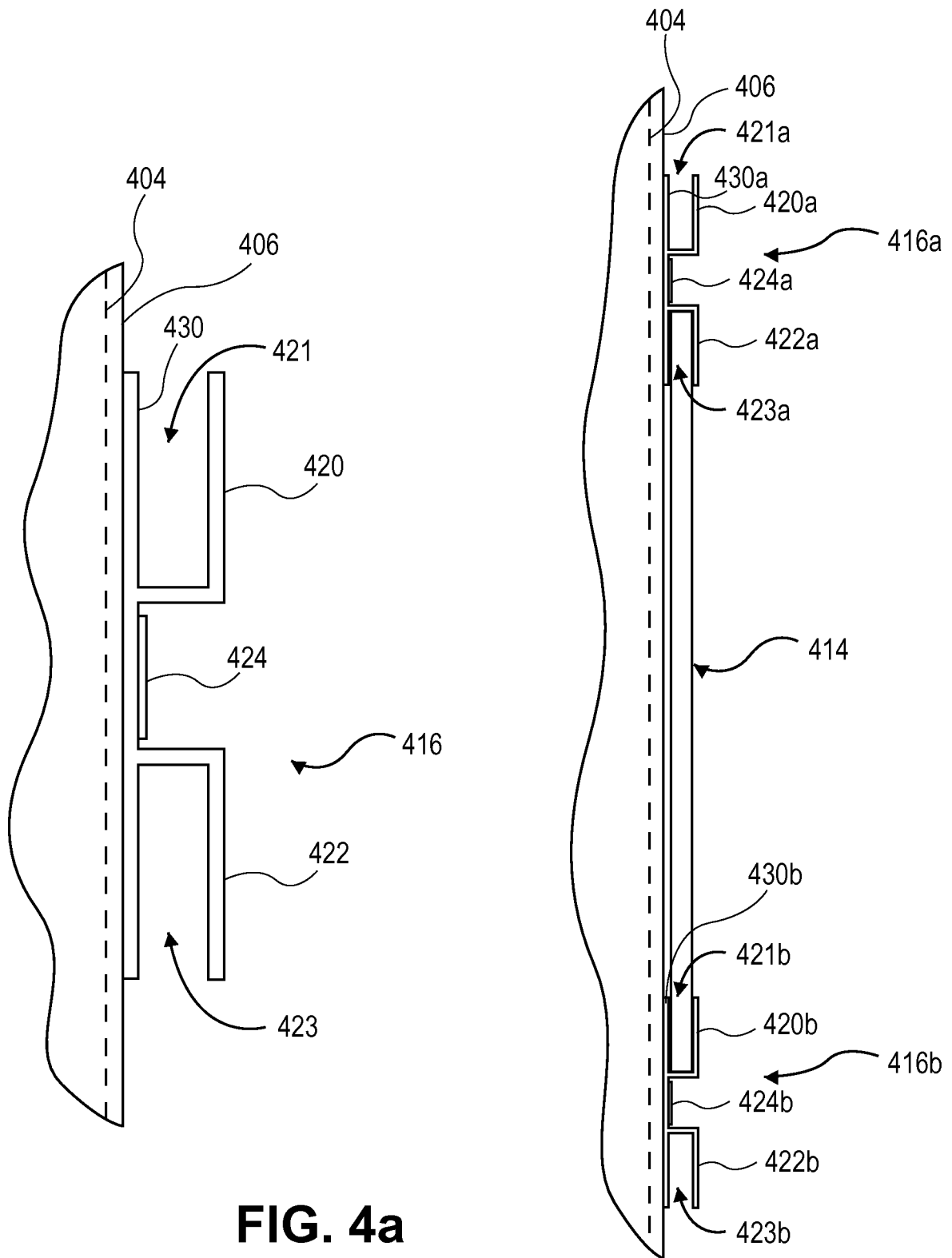


FIG. 4a

FIG. 4b

11/12

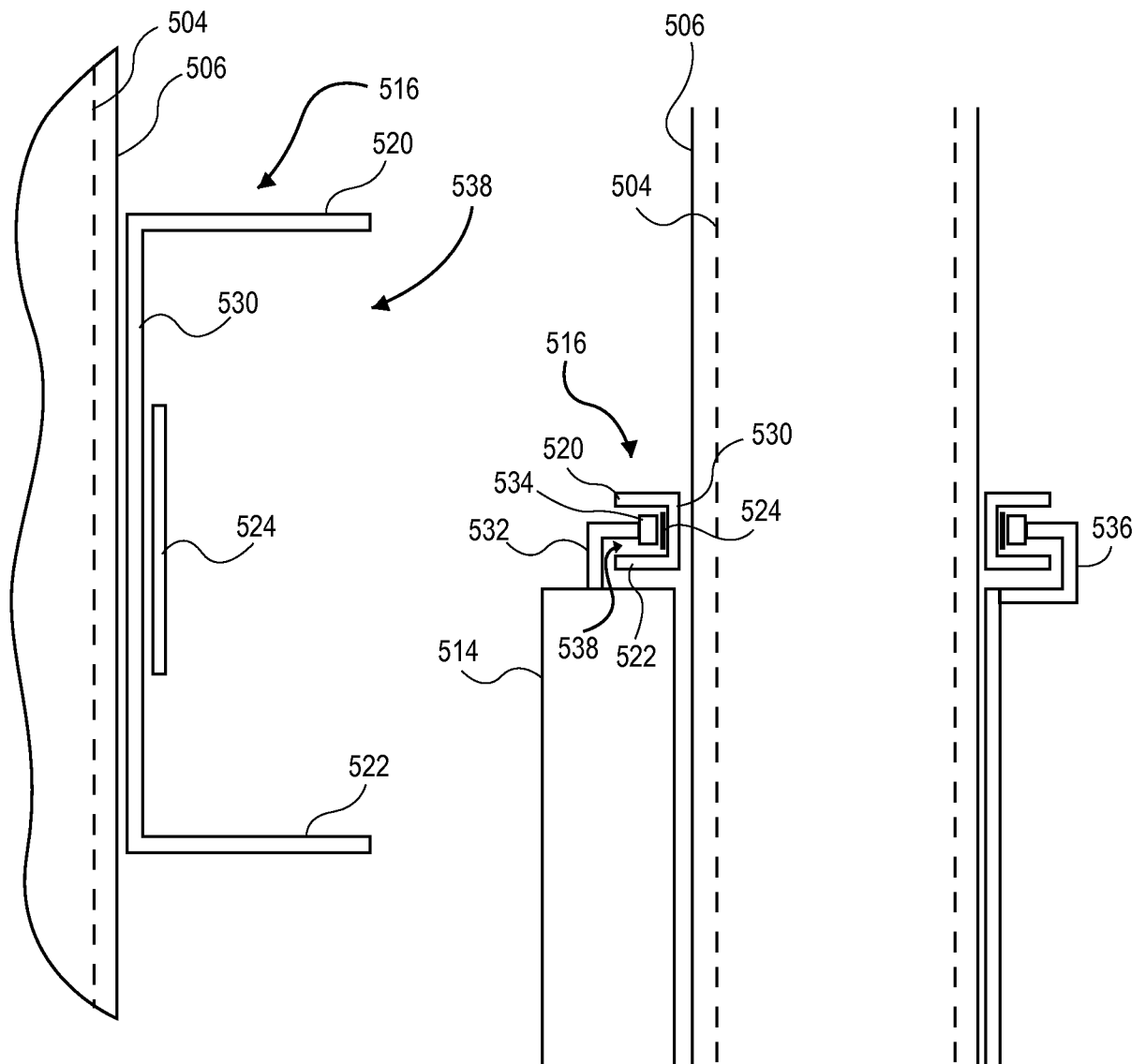


FIG. 5a

FIG. 5b

12/12

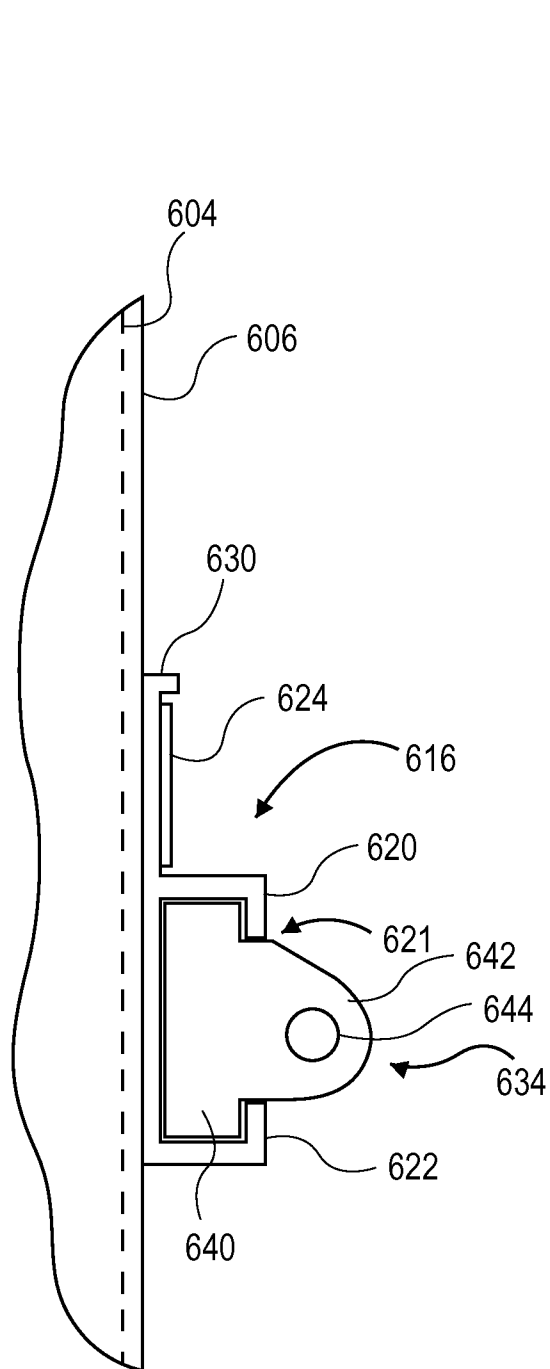


FIG. 6a

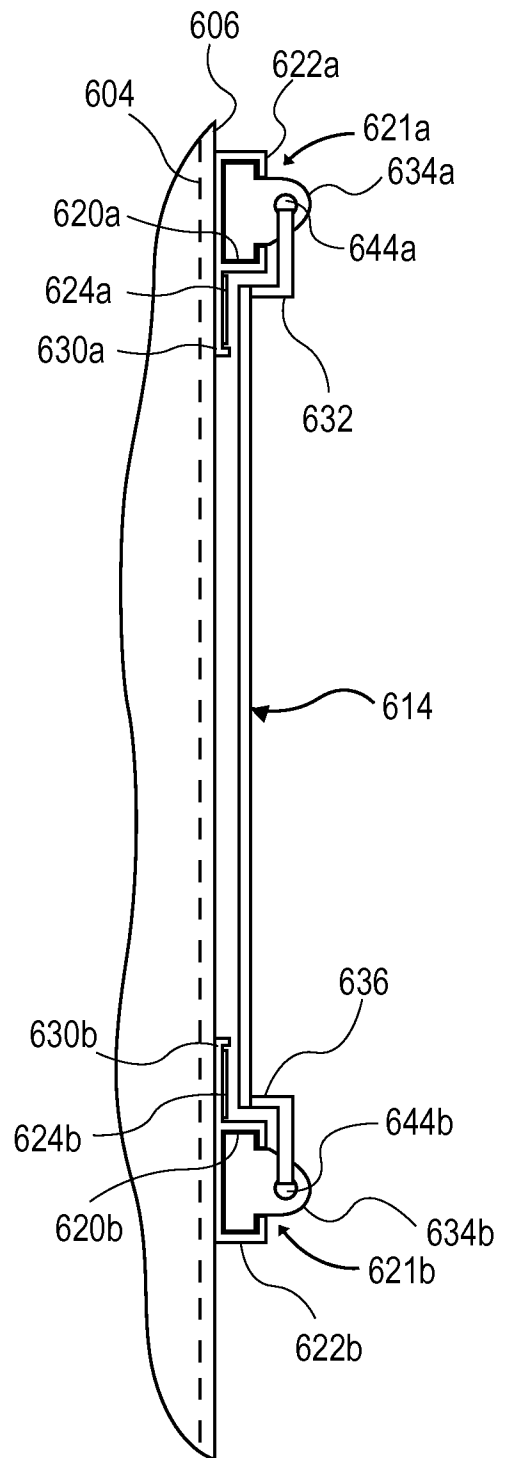


FIG. 6b

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 09/31501

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - E02D 5/60 (2009.01)

USPC - 405/211

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

USPC 405/211

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC 405/211, 195.1, 224.2 (text search--see below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PubWest (PGPB,USPT,EPAB,JPAB); Google Scholar

Search Terms: VIV, vortex-induced vibration, suppression, reduction, weathervane, turn rotate, riser, umbilical, tendon, foam, buoyant, insulation, sleeve, covering, holder, guide, collar, bearing

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2007/0215028 A1 (LIE) 20 September 2007 (20.09.2007) entire document, especially FIG. 1 and para [0030]-[0039]	1-2, 15
A	US 6,669,408 B1 (WOODALL et al.) 30 December 2003 (30.12.2003) entire document, especially FIGs. 1-3 and col. 3, ln 11-45	1, 15

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

24 February 2009 (24.02.2009)

Date of mailing of the international search report

10 MAR 2009

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-3201

Authorized officer:

Lee W. Young

PCT Helpdesk: 571-272-4300

PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 09/31501

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☒ Claims Nos.: 3-14
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.