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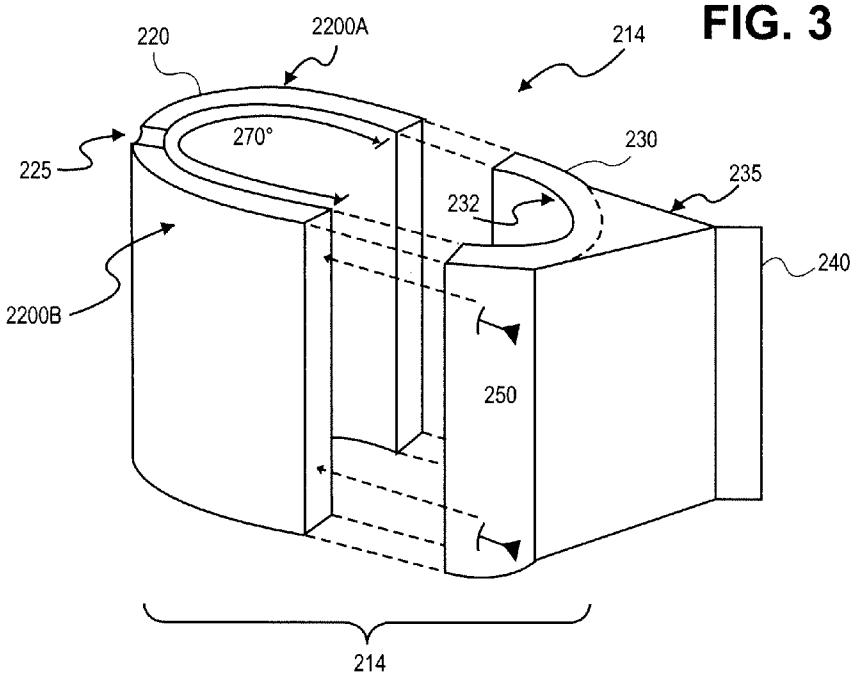
FIG. 3



(57) Abstract: A system comprising a vortex induced vibration suppression device comprising a base section comprising at least two connected portions; and a tail section connected to the base section.

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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

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 vortexes. 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.

U.S. Patent 6,401,646 discloses a fairing system for the reduction of vortex-induced vibration and minimization of drag about a substantially cylindrical element immersed in a fluid medium. The fairing system includes a plurality of cylindrical

shells rotatably mounted about a cylindrical element immersed in a fluid medium. Each cylindrical shell has opposing edges defining a longitudinal gap configured to allow the shells to snap around the cylindrical element. The longitudinal gap has a circumference of about 120° relative to the circumference of each shell. Alternatively the longitudinal gap can have a circumference of about 60° relative to the circumference of each shell. The shells also include a fin positioned along the each opposing edge of the longitudinal gap, in which each fin extends outwardly from each shell. The fins are positioned on each shell so as to reduce vortex-induced vibration and minimize drag on the cylindrical element. U.S. Patent 6,401,646 is herein incorporated by reference in its entirety.

U.S. Patent 5,738,034 discloses an apparatus and method for minimizing vortex induced vibrations and hydrodynamic drag of a drilling riser. Vortex induced vibrations and hydrodynamic drag are minimized by installing on a drilling riser streamlined faring sections. The fairing sections are installed on and removed from a riser through the use of one or more door panels on a rounded front portion that have a latch mechanism which can be easily opened and closed. The fairing sections are configured so they can nest one inside the other for easy storage. A tapered back or tail section of each fairing section has an attachment receptacle for engagement by a handling mechanism with a telescoping arm for grasping the fairing section. The handling mechanism is designed to move the fairing sections between a rack, where they are stored, and a position adjacent to the riser. U.S. Patent 5,738,034 is herein incorporated by reference in its entirety.

VIV suppression devices such as fairings are often installed from floating structures such as boats, ships, tension leg platforms, or spars. As such, the buoyancy, storage, and deck capacity are limited. Traditional full coverage fairings are typically manufactured from fiberglass or metals or other dense materials. In addition, the fairing devices are bulky and difficult to store efficiently.

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 with a light weight device.

There is a need for systems and methods of storing VIV suppression devices by stacking them.

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 vortex induced vibration suppression device comprising a base section comprising at least two connected portions; and a tail section connected to the base section.

In another aspect, the invention provides a method of reducing drag and/or vortex induced vibration of a subsea structure, comprising installing the subsea structure in a body of water, wherein the subsea structure is subject to one or more water currents; and installing a vortex induced vibration suppression device exterior to the subsea structure, the vortex induced vibration suppression device comprising a base section comprising at least two connected portions; and a tail section connected to the base section.

Brief Description of the Figures

Features, aspects, and advantages of embodiments will become more thoroughly apparent from the following detailed description, appended claims, and accompanying drawings in which:

Figure 1 illustrates a subsea structure system.

Figure 2 illustrates a top side view of an embodiment of a VIV suppression device in a collapsed configuration.

Figure 3 shows a top, side perspective view of the VIV suppression device of Figure 3 in an exploded, deployed configuration.

Figure 4 shows a top, side perspective view of another embodiment of a VIV suppression device in an exploded, deployed configuration.

Figure 5 shows the VIV suppression device of Figure 4 in a collapsed configuration.

Figure 6 shows a top, side perspective view of another embodiment of a VIV suppression device in an exploded, deployed configuration.

Figure 7 shows the VIV suppression device of Figure 6 in a collapsed configuration.

Figure 8 shows a top, side perspective of another embodiment of a VIV suppression device in a deployed configuration.

Figure 9 shows the VIV suppression device of Figure 8 in a collapsed configuration.

Figure 10 shows a top view of another embodiment of a VIV suppression device in a collapsed configuration.

Figure 11 shows a top, side perspective view of the device of Figure 10 in a deployed confirmation.

Figure 12 shows a side view of a rig having a riser assembly disposed through a rotary table and the riser assembly having a portion of a VIV suppression device attached thereto.

Figure 13 shows the rig of Figure 12 following the connection of a tail of the suppression device.

Figure 14 shows an exploded side view of a collar on a riser assembly with a tail of a VIV suppression device attached to a ring about the collar.

Detailed Description

Referring to Figure 1, there is illustrated offshore system 100. System 100 includes surface structure 102 near the water surface. System 100 is connected to riser 104, which riser 104 is connected to subsurface structure 106, which is adjacent to seafloor 108. Exterior to riser 104, in this embodiment, is buoyancy material 108 (e.g., a foam material), which may serve to insulate and/or provide buoyancy to riser 104. The water has current 110, which may cause vortex-induced vibration (VIV) of riser 104. To counter VIV, VIV suppression devices 114 may be installed along the

length of riser 104. Collars 112 may be used to keep individual VIV suppression devices 114 from moving along the length of riser 104.

Riser assemblies or systems are defined to be a non-exclusive example of a marine element subject to VIV. Generally, a riser assembly is used for establishing fluid communication between the surface and the bottom of the water body. A 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 assembly normally includes one or more fluid-conducting conduits which extend from the surface to a structure (e.g., a wellhead) on the bottom of a water body. For example, in the drilling of a submerged well, a drilling riser usually includes a main conduit through which the drill string is lowered and through which drilling mud is circulated from the lower end of the drill string back to the surface. In addition to the main conduit, there are generally provided auxiliary conduits such as, for example, choke and kill lines, pressurized fluid lines, hard pipes and electrical lines, that extend relatively parallel to the main conduit. These auxiliary conduits and lines are commonly referred to as umbilical elements and/or umbilicals. Such umbilical element(s) may be disposed through buoyancy material 108 or may be positioned exterior to buoyancy material 108. For those umbilical element(s) that are exterior to buoyancy material 108, holders may be positioned inside each VIV suppression device 114 to allow the suppression device to rotate without interfering with the umbilical element(s).

Figure 2 and Figure 3 show an embodiment of a VIV suppression device that may be attached/detached to a riser assembly during riser deployment/recovery. In one embodiment, VIV suppression device 214 is a full coverage VIV suppression device made of a relatively lightweight material compared to commercially available full coverage VIV suppression devices (e.g., fiberglass devices). By "full coverage" is meant that the suppression device covers substantially the entire circumference of a riser. A riser, in one embodiment, has a length on the order of 40-90 feet. Suitable materials for VIV suppression device 214 include, but are not limited to, polymeric (plastic) materials that have a specific weight on the order of 100 pounds per cubic foot or less, for example less than about 90, 75, or 50 pounds per cubic foot. Such

materials include, but are not limited to, polyethylene and polypropylene polymers, e.g., high density polypropylene.

In the embodiment shown in Figure 2 and Figure 3, VIV suppression device 214 includes base 220 and tail 230. Each of base 220 and tail 230 are made of a lightweight material such as plastic. Base 220 and tail 230 of a plastic material may be formed by molding or extrusion techniques. Base 220 is divided into first portion 2200A and second portion 2200B that are connected together through hinged joint 225. When deployed (e.g., as in Figure 3), base 220 of first portion 2200A and second portion 2200B constitute an approximately 270° portion of a circumference of VIV suppression device 214. In one embodiment, first portion 2200A and second portion 2200B are of a similar circumferential (width) dimension, W, each accounting for approximately 135° of a circumference of the VIV suppression device. In other embodiments, the width dimensions may be different.

First portion 2200A and second portion 2200B are connected in such a way that first portion 2200A and second portion 2200B may turn or pivot relative to one another. Figure 2 and Figure 3 show hinged joint 225 of a living hinge which is a hinge with no moving parts and is represented by relatively thin section of the material (e.g., a plastic material of which first portion 2200A and second portion 2200B are made) that allows movement of first portion 2200A and second portion 2200B relative to one another. Alternatively, first portion 2200A and second portion 2200B may be connected at hinged joint 225 by a mechanical device such as a hinge of various types that allows rotation between the two portions. Suitable hinges include, but are not limited to, one or more butt hinges or a continuous hinge (piano hinge) that representatively runs the entire length of hinged joint 225. The hinges may be made out of a plastic material or a metal material such as a corrosion resistant metal material (e.g., stainless steel, inconel, or fiberglass). Figure 2 shows first portion 2200A and second portion 2200B pivoted away from one another. Figure 3 shows first portion 2200A and second portion 2200B pivoted towards one another to form, in this embodiment, a 270° section of VIV suppression device 214.

In addition to base 220, VIV suppression device 214 includes tail 230. In the embodiment shown in Figure 2 and Figure 3, tail 230 is separate from base 220. Tail

230 may have a length dimension, L2, equivalent to a length dimension, L1, of base 220. In this embodiment, tail 230 includes cylindrical portion 232 having ends that are intended to be connected to ends of base 220 so that when connected, base 220 and cylindrical portion 232 of tail 230 define a cylindrical body for VIV suppression device 214. In other words, cylindrical portion 232 forms a portion of a cylinder that when connected to the free ends of base 220 (i.e., free ends of first portion 2200A and second portion 2200B), the connected structures define a cylindrical body having a chamber or lumen having a circumference of 360°.

Tail 230 of VIV suppression device 214 also includes fairing portion 235 having a shape defined by a plane figure connecting three points not in a straight line, such as a triangular shape, with an apex extending away from cylindrical portion 232. The sides of fairing 235 between cylindrical portion 232 and the apex are illustrated in Figure 3 as linear. It is appreciated that non-linear forms are also suitable (e.g., concave or convex). As illustrated, cylindrical portion 232 and fairing portion 235 of tail 230 are a single body of material, such as a molded or extruded plastic body. In another embodiment, cylindrical portion 232 and fairing 235 may be separate pieces that are connected together such as by pinning, nut/bolt, screw, or adhesive. In the embodiment shown in Figure 2 and Figure 3, tail 230 also includes optional splitter 240 connected at the apex of fairing 235, for example by sliding splitter 240 into a slot in tail 230, and securing. Splitter 240 may be formed as an integral piece with cylindrical portion 232 and fairing portion 235 of tail 230 or may be separately connected such as by pinning, screws, nut/bolt, adhesive, etc. In another embodiment, there may be provided a dual tail arrangement as disclosed in U.S. Patent Number 6,401,646, which is herein incorporated by reference in its entirety.

In the embodiment shown in Figure 2 and Figure 3, base 220 and tail 230 may be connected around a tubular (for example a riser with buoyancy) by connecting the ends of first portion 2200A and second portion 2200B with the ends of cylindrical portion 232 of tail 230. As described with reference to Figures 12-13 and the accompanying text, base 220 and tail 230 may be installed around riser at approximately the same time or base 220 may be installed first followed by the installation of tail 230 and the connection of the base and the tail. For example, base

220 may be pre-installed on a riser or a riser buoyancy prior to the riser installation, such as by temporarily pinning base 220 to the riser or riser buoyancy. The riser including the base may be installed and tail 230 is then connected to base 220 below a rotary table of a rig. The connection may be through pins, nails, bolts, screws, adhesive, or other fasteners. Figure 3 shows pins 250 (e.g., stainless steel pins) that may be inserted through cylindrical portion 232 of tail 230 into base 220 to secure tail 230 to the base.

VIV suppression device 214 may be formed around a riser or a riser, umbilical(s), and buoyancy material or other structures potentially subject to VIV. When assembled around a riser or similar structure, suppression device 214 defines an inner interior diameter of, for example, a cylindrical shape that is larger than the riser and any buoyancy material and/or umbilical(s). In this way, suppression device 214 may fit around and/or weathervane about the structure.

In one embodiment, VIV suppression device 214 can be attached to riser assembly during riser deployment/recovery. Because base 220 and tail 230 of VIV suppression device are each made of a lightweight material such as a lightweight plastic, the suppression devices can be handled and installed/removed more quickly than prior art full coverage devices, such as full coverage fiberglass suppression devices.

In the above embodiment shown in Figure 2 and Figure 3, tail 230 was described as a single piece including cylindrical portion 232 and fairing 235 (and optionally, splitter 240) or a combination of individual connected parts. Figure 4 shows an embodiment where a tail is made up of at least two connected components. Referring to Figure 4, suppression device 414 includes base 420 made up of first portion 4200A and second portion 4200B that are connected through hinged joint 425 in any of the various ways described above with respect to Figure 2 and Figure 3 and the accompanying text. First portion 4200A and second portion 4200B form a cylindrical structure of approximately 270° inner circumference. Figure 4 also shows tail 430 made up of individual cylindrical portions 432A, 432B and fairing portions 435A, 435B, respectively. Fairing portion 435A includes, in one embodiment, optional splitter 440 connected at an apex thereof. In this embodiment, cylindrical portion

432A and cylindrical portion 432B of tail 430 are individually connected to respective ends of first portion 4200A and second portion 4200B of base 420. Fairing portion 435A and fairing portion 435B are connected to one another to form tail 430 as a unitary structure. In this embodiment, fairing portion 435A has window 437A defining a passage through opposing sides of the fairing portion. Fairing portion 435B has window 437B defining a passage through opposing sides of the fairing portion. In one embodiment, bolt 438 may be inserted through a passage in window 437B through fairing portion 435B into a passage of window 437A through fairing portion 435A. An end of bolt 438 may be secured by nut 439 to fasten fairing portion 435A to fairing portion 435B. Although a nut and bolt fastening configuration is shown, other fastening systems are also suitable, including, but not limited to, nails, bolts, screws, pins, and/or adhesive. Following attachment of the fairing portions through the windows in the fairing portions, the openings may be covered by, for example, cover 451.

The component parts of VIV suppression device 414 (e.g., base 420, tail 430) may be formed of a lightweight material such as molded or extruded plastic. One advantage of VIV suppression device 414 shown in Figure 4 is the stackability of the component parts prior to deployment on a riser system or similar structure. Figure 5 shows a side view of body 420 opened in a nesting arrangement with other body portions. Similarly, Figure 5 shows fairing portion 435A and fairing portion 435B in nesting arrangement with other fairing portions.

Figure 6 shows another embodiment of a VIV suppression device. In this embodiment, VIV suppression device 614 includes base 620 including first portion 6200A, second portion 6200B and third portion 6200C connected by hinged joints 625AB and 625BC. Butt hinges are representatively shown (at joint 625BC) but it is appreciated that other hinge assemblies including, but not limited to, living hinges or continuous hinges may be substituted. In one embodiment, base 620 may be assembled around a riser, buoyancy material on a riser or similar structure by enclosing hinged joints 625AB and 625BC. The closure around the riser, buoyancy material or similar structure will connect ends of first portion 6200A and third portion

6200C. The ends may then be connected such as by pins or screws or other mechanisms, defining joint 625AC.

VIV suppression device 614 also includes tail 630. In this embodiment, tail 630 includes individual tail portion 635A and individual tail portion 635B that may individually be connected to base 620. In one embodiment, the connection of a tail portion to base 620 is done through the hinges. Figure 6 shows each of tail portion 635A and tail portion 635B having hinge portion 662 (e.g., a male portion) that is intended to join with and mate with hinge portion 663 (e.g., a female portion) on an exterior base 620. Following the hinged connection of tail portion 635A and tail portion 635B to base 620, the opposite ends of each tail portion may be brought together and secured, for example, through a nut and bolt configuration (e.g., similar to that described with reference to Figure 4 and the accompanying text). Figure 6 shows tail portion 635A including window 637A including a passage therethrough and tail portion 635B having window 637B also with a passage therethrough. Bolt 638 may be inserted through the passage in window 637B, through the passage in window 637A and secured by bolt 639 to connect the tail portion.

Figure 7 shows VIV suppression device 614 in a collapsed or undeployed configuration. Figure 7 illustrates that, in this configuration, the suppression device does not occupy a lot of space since it may be collapsed and may be nested with other similar suppression devices.

Figure 8 shows another embodiment of a VIV suppression device. In this embodiment, VIV suppression device 814 includes base 820 that is made up of four portions: first portion 8200A, second portion 8200B, third portion 8200C and fourth portion 8200D. Each portion of base 820, in this embodiment, has a circumferential width of 90° so that when placed end to end widthwise, the portions form a cylindrical structure of approximately 360° inner circumference. In this embodiment, the portions that make up base 820 are not hinged together but may be connected once the portions are on (against) a riser, buoyancy material or similar structure. Representatively, the portions may be connected by pinning. Figure 8 shows pins 850 connecting portions 8200C and 8200D. For deployment on a riser, the individual portions (first portion 8200A, second portion 8200B, third portion 8200C and fourth

portion 8200D) may be individually placed on a riser or similar structure and thereafter connected to another portion. Where the individual portions of base 820 are made of a plastic material (e.g., extruded or molded plastic), the portions may be relatively lightweight and are easily maneuverable on a rig either above or below a rotary table relative to, for example, a fiberglass full coverage device.

VIV suppression device 814 also includes tail 830. In this embodiment, tail 830 includes individual tail portion 835A and individual tail portion 835B that may be individually connected to base 820. In one embodiment, the connection of a tail portion of base 820 is done through pins 833. An opposite end of each of tail portion 835A and tail portion 835B are brought together and the tail portion connected through, for example, a nut and bolt configuration (e.g., similar to that described in reference to Figure 4 and the accompanying text).

Figure 9 shows VIV suppression device in a disassembled or undeployed configuration. Figure 9 illustrates that the individual portion of base 820 and tail 830 may be stacked and nested with other similar suppression devices and therefore do not occupy a lot of space.

Figure 10 and Figure 11 show another embodiment of a VIV suppression device (e.g., a full coverage suppression device) that may be attached/detached to a riser assembly during riser deployment/recovery. Similar to the other embodiments, VIV suppression device 1014 may be made of a relatively lightweight material compared to prior art fiberglass full coverage VIV suppression devices. In the embodiment shown in Figure 10 and Figure 11, VIV suppression device includes base 1020 and tail 1030. Each of base 1020 and tail 1030 are made of a lightweight material such as plastic formed by a molding or extrusion techniques. Base 1020 is divided into first portion 10200A and second portion 10200B that are connected through hinged joint 1025AB in such a way that first portion 10200A and second portion 10200B may pivot relative to one another. Figure 10 shows hinged joint 1025AB formed by a number of butt hinges 1023. It is appreciated that other hinges may be suitable, including a living hinge or continuous hinge. When deployed (e.g., as in Figure 11), base 1020 of first portion 10200A and second portion 10200B

constitute an approximately 270° portion of a circumference of VIV suppression device 1014.

In addition to base 1020, VIV suppression device 1014 includes tail 1030. In the embodiment shown in Figure 10 and Figure 11, tail 1030 has a length dimension equivalent to a length dimension of base 1020. In this embodiment, tail 1030 has a linear base 10300A and apex 10300B and is defined by a plane figure connecting three points not in a straight line, such as a triangle (as shown). It is appreciated that base 10300A need not be linear and that the sides of tail 1030 connecting base 10300A and apex 10300B need not be linear (e.g., concave or convex). Tail 1030 is connected to base 1020 through hinged joint 1025BC. Figure 10 shows several butt hinges 1033 connected to second portion 10200B and to one side of tail 1030 along a length dimension. It is appreciated that other hinge devices/mechanisms may be substituted.

Figure 11 shows base 1020 in a closed position and tail 1030 in contact with an end of first portion 10200A of base 1020. Base 10300A of tail 1030 is illustrated in Figure 11 to be linear. In this manner, a lumen or passage defined by base 1020 and tail 1030 has a U-shape. The cavity may be used to enclose a riser assembly including umbilicals (e.g., external umbilicals). A free end (i.e., the non-hinged end) of tail 1030 may then be connected to first portion 10200A of base 1020 by, for example, pins 1033 or other connecting device (e.g., screws, adhesive, hinges).

Figure 12 and Figure 13 show an embodiment of a VIV suppression device 1214 on a riser assembly below a rotary table of a rig. VIV suppression device 1214 may representatively be similar to any of the devices described with reference to Figures 2-9 and the accompanying text where a tail of a VIV suppression device is separate from a base. Figure 12 shows riser 1204 having buoyancy material 1208 covering a length of riser 1204. Figure 12 also shows base 1220 of VIV suppression device 1214 connected to buoyancy material 1208. In one embodiment, base 1220 is temporarily connected (e.g., pinned) to buoyancy material 1208 prior to the deployment of the riser assembly through rotary table 1215. Alternatively, base 1220 need not be temporarily connected to buoyancy material 1208 but may be installed after a riser assembly is deployed through rotary table 1215. Regardless of whether

base 1220 is installed above or below a rig's rotary table, the lightweight, hinged arrangement will install at a more acceptable rate than commercially available VIV suppression devices.

As shown in Figure 12, riser 1204 is deployed through rotary table 1215 to a position below the rotary table. Following deployment of the riser assembly below the rotary table, collars 1212 may be installed around the riser assembly to maintain a position of VIV suppression device 1214. Alternatively, low-profile collars may be used that fit through an opening in rotary table 1215 so that collars 1212 may be installed above the rotary table with, for example, base 1220. Following the deployment of riser 1214 below rotary table 1215, tail 1230 is connected to base 1220 of VIV suppression device 1214. Representatively, tail 1230 can be connected to base 1220 using one of the techniques described above with reference to Figures 2-9 and the accompanying text. Figure 13 shows tail 1230 connected to base 1220. If base 1220 had been previously pinned or otherwise connected to the riser assembly (e.g., to buoyancy material 1208), base 1220 may be freed (e.g., by removing any pins) so that VIV suppression device 1214 may weathervane about the riser assembly.

In another embodiment, rather than temporarily connecting a base of a VIV suppression device to a riser assembly (e.g., a buoyancy material), collars may be provided with a lip such that the base can rest on the lip. In this embodiment, the collar on which the suppression device is rested would be positioned below the base of the VIV suppression device.

With the embodiment shown in reference to Figure 12 and Figure 13, specific reference was made to embodiments of VIV suppression devices described with reference to Figures 2-9 and the accompanying text. It is appreciated that a device such as shown in Figures 10-11 wherein a VIV suppression device includes a base and tail that are connected together pre-deployment by, for example, hinged joints, it may not be possible to install such a device on a riser assembly before the riser assembly is deployed through a rotary table. In such a circumstance, the VIV suppression device shown in Figures 10-11 may be installed on a riser assembly after the riser assembly is deployed through a rotary table. Where a VIV suppression

device such as illustrated in Figures 10-11 is made of a lightweight material such as plastic, the device, even if connected as illustrated may be more easily maneuvered and handled than commercially available full coverage fiberglass devices.

Each of embodiments in Figures 2-11 describe a VIV suppression device that includes a tail including a fairing optionally with a splitter connected thereto. In another embodiment, a tail of a VIV suppression device includes one or more splitters without a fairing.

Each of the embodiments in Figures 2-11 describe a VIV suppression device but include a base intended to surround a riser assembly. In another embodiment, a VIV suppression device is a fairing and/or splitter(s) connected to buoyancy material. In this embodiment, the buoyancy material is free to rotate relative to the riser inside of it (including other tubulars, the riser pipe, and inner buoyancy, if present). The tail and/or splitter(s) may be connected to the buoyancy material by pinning, adhesive or another mechanism.

In the embodiment described in Figure 12 and Figure 13, tail 1230 is connected to base 1220. In another embodiment, rather than connecting a tail to a base, a tail may be connected to a collar. Figure 14 shows riser 1404 with buoyancy material 1408 disposed thereon. Figure 14 also shows base 1420 of a VIV suppression device disposed on buoyancy material 1408. Base 1420 may be connected to buoyancy material (e.g., through pinning) or may be free to rotate about buoyancy material 1408. In one embodiment, base 1420 is a cylindrical structure of approximately 360° inner circumference that surrounds buoyancy material 1408.

Figure 14 also shows two-piece collar 1412 intended to be placed on an end of riser assembly 1408. Collar 1412 is a two-piece collar made up of, representatively, two U-shaped portions that will connect to riser 1404. Each of the U-shaped portions of collar 1412 includes a slotted end in which ring portions that make up ring 1415 are seated such that the ring can rotate in the slot provided. Collar 1412 and ring 1415 are made of a corrosion resistant material such as copper, inconel, fiberglass, thermoplastics, or stainless steel.

In the embodiment shown in Figure 14, the VIV suppression device also includes tail 1430. Rather than connecting tail 1432 to base 1420, in this

embodiment, tail 1430 is connected to an outer portion of ring 1415 associated with collar 1412. Tail 1430 is formed of a plastic material that includes main body portion 1470 and inverted L-shaped portion 1475 extending from a superior surface of main body portion 1470. An end of a base of inverted L-shaped portion 1475 includes eyelet 1480 that may be aligned with eyelet 1416 provided on ring 1415 (on one of the ring portions). Tail 1430 may be connected to ring 1415 through the insertion of pin 1490 through eyelet 1416 and eyelet 1480. A suitable pin is a cotter pin or similar structure. Tail 1430 may be connected in such a way that it may weathervane on ring 1415 around base 1420. It is appreciated that, if necessary, a similar connection may be made at the base (as viewed) of tail 1430 (connecting to a collar installed below the VIV suppression device).

In another embodiment, rather than attaching tail 1430 to ring 1415 during the deployment on a riser assembly, a rotating ring may be pre-attached to a fairing tail and hinged so that the assembly can be brought into position (e.g., about a collar) and enclosed below a rotary table. Still another embodiment provides a rotating ring above or below the collar rather than about the collar. Such an embodiment will tend to minimize the precision required during assembly of the collar and ring on a rig.

In the above described embodiment, VIV suppression devices are described with reference generally to fairing devices. It is appreciated that the concept of a lightweight material (e.g., a lightweight plastic) and multi-component, easily connected devices may be applied to polygonal devices, smooth sleeve, splitter(s) and strake (e.g., helical strake). For some of these devices, it may not be necessary for the device to rotate so it can be attached to buoyancy material or collar(s) of a structure (e.g., piping) and not be free to rotate.

In the preceding detailed description, reference is made to specific embodiments thereof. It will, however, be evident that various modifications and changes may be made thereto without departing from the broader spirit and scope of the following claims. The specification and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense.

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 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 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, or have copper strips installed on an inner surface to retard marine growth, and/or be coated with an anti-fouling paint or other coating.

Illustrative Embodiments:

In one embodiment, there is disclosed a system comprising a vortex induced vibration suppression device comprising a base section comprising at least two connected portions; and a tail section connected to the base section. In some embodiments, the device is installed about a circumference of a subsea structure, the subsea structure selected from an umbilical, a riser, and a tendon. In some embodiments, the base section comprises a hinged joint between the at least two connected portions. In some embodiments, the vortex induced vibration suppression device comprises a fairing. In some embodiments, the base section comprises an arc length from about 180 to about 360 degrees about a circumference of a subsea structure. In some embodiments, the tail section comprises an arc length from about 45 to about 180 degrees about a circumference of a subsea structure. In some embodiments, the tail section comprises a splitter plate. In some embodiments, at least one of the base section and the tail section comprise a polymer, the polymer selected from the group consisting of polypropylene and polyethylene. In some embodiments, the system also includes a connection mechanism between the base section and the tail section, the connection mechanism selected from the group consisting of pins, nails, screws, bolts, adhesives, rivets, and other connection mechanisms as are known in the art. In some embodiments, the tail section comprises at least two portions. In some embodiments, the base section comprises an arc length of about 360 degrees about a circumference of a subsea structure. In some embodiments, the tail section comprises a male connector portion, and the base section comprises a female connector portion, the male connector portion adapted to mate with the female connector portion to secure the tail section to the base section. In some embodiments, the base section comprises at least about 3

interconnected portions. In some embodiments, the base section comprises at least about 4 interconnected portions. In some embodiments, the system also includes a hinged connection interconnecting the base section and the tail section.

In one embodiment, there is disclosed a method of reducing drag and/or vortex induced vibration of a subsea structure, comprising installing the subsea structure in a body of water, wherein the subsea structure is subject to one or more water currents; and installing a vortex induced vibration suppression device exterior to the subsea structure, the vortex induced vibration suppression device comprising a base section comprising at least two connected portions; and a tail section connected to the base section. In some embodiments, the vortex induced vibration suppression device comprises a fairing. In some embodiments, the vortex induced vibration suppression device is adapted to rotate about the subsea structure in response to the one or more water currents. In some embodiments, the method also includes installing a covering exterior to the subsea structure, covering at least a portion of an outside surface of the subsea structure, then installing the vortex induced vibration suppression device exterior to the covering. In some embodiments, the method also includes installing one or more collars exterior to the subsea structure between vortex induced vibration suppression devices.

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.

CLAIMS

1. A vortex induced vibration suppression device comprising:
a base section comprising at least two connected portions; and
a tail section connected to the base section.

2. The device of claim 1, wherein the device is installed about a circumference of a subsea structure, the subsea structure selected from an umbilical, a riser, and a tendon.

3. The system of one or more of claims 1-2, wherein the base section comprises a hinged joint between the at least two connected portions.

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, wherein the base section comprises an arc length from about 180 to about 360 degrees about a circumference of a subsea structure.

6. The system of one or more of claims 1-5, wherein the tail section comprises an arc length from about 45 to about 180 degrees about a circumference of a subsea structure.

7. The system of one or more of claims 1-6, wherein the tail section comprises a splitter plate.

8. The system of one or more of claims 1-7, wherein at least one of the base section and the tail section comprise a polymer, the polymer selected from the group consisting of polypropylene and polyethylene.

9. The system of one or more of claims 1-8, further comprising a connection mechanism between the base section and the tail section, the connection mechanism selected from the group consisting of pins, nails, screws, bolts, adhesives, rivets, and other connection mechanisms as are known in the art.

10. The system of one or more of claims 1-9, wherein the tail section comprises at least two portions.

11. The system of one or more of claims 1-10, wherein base section comprises an arc length of about 360 degrees about a circumference of a subsea structure .

12. The system of one or more of claims 1-11, wherein the tail section comprises a male connector portion, and the base section comprises a female connector portion, the male connector portion adapted to mate with the female connector portion to secure the tail section to the base section.

13. The system of one or more of claims 1-12, wherein the base section comprises at least about 3 interconnected portions.

14. The system of one or more of claims 1-13, wherein the base section comprises at least about 4 interconnected portions.

15. The system of one or more of claims 1-14, further comprising a hinged connection interconnecting the base section and the tail section.

16. A method of reducing drag and/or vortex induced vibration of a subsea structure, comprising:

installing the subsea structure in a body of water, wherein the subsea structure is subject to one or more water currents; and

installing a vortex induced vibration suppression device exterior to the subsea structure, the vortex induced vibration suppression device comprising a base section comprising at least two connected portions; and a tail section connected to the base section.

17. The method of claim 16, wherein the vortex induced vibration suppression device comprises a fairing.

18. The method of one or more of claims 16-17, wherein the vortex induced vibration suppression device is adapted to rotate about the subsea structure in response to the one or more water currents.

19. The method of one or more of claims 16-18, further comprising installing a covering exterior to the subsea structure, covering at least a portion of an outside surface of the subsea structure, then installing the vortex induced vibration suppression device exterior to the covering.

20. The method of one or more of claims 16-19, further comprising installing one or more collars exterior to the subsea structure between vortex induced vibration suppression devices.

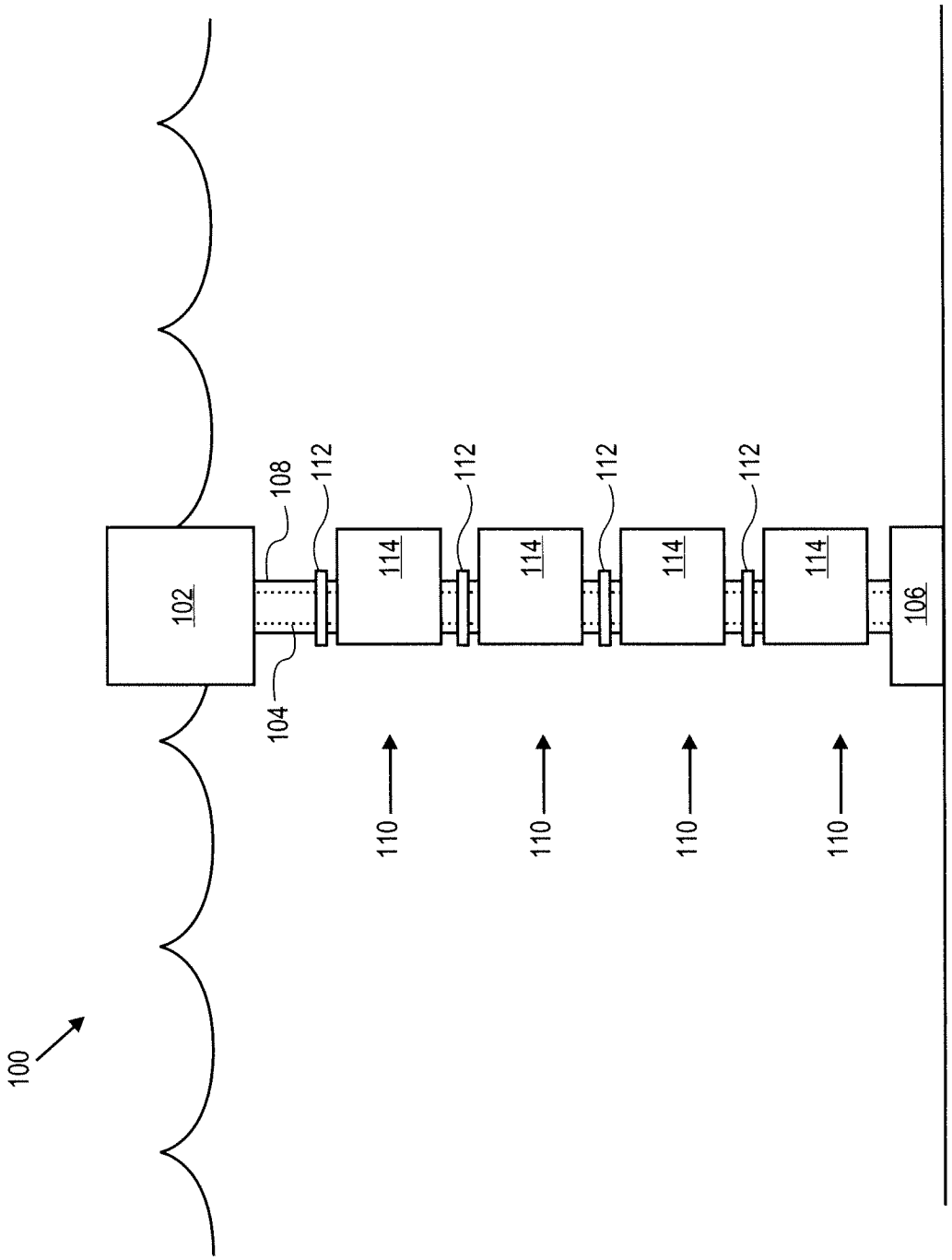
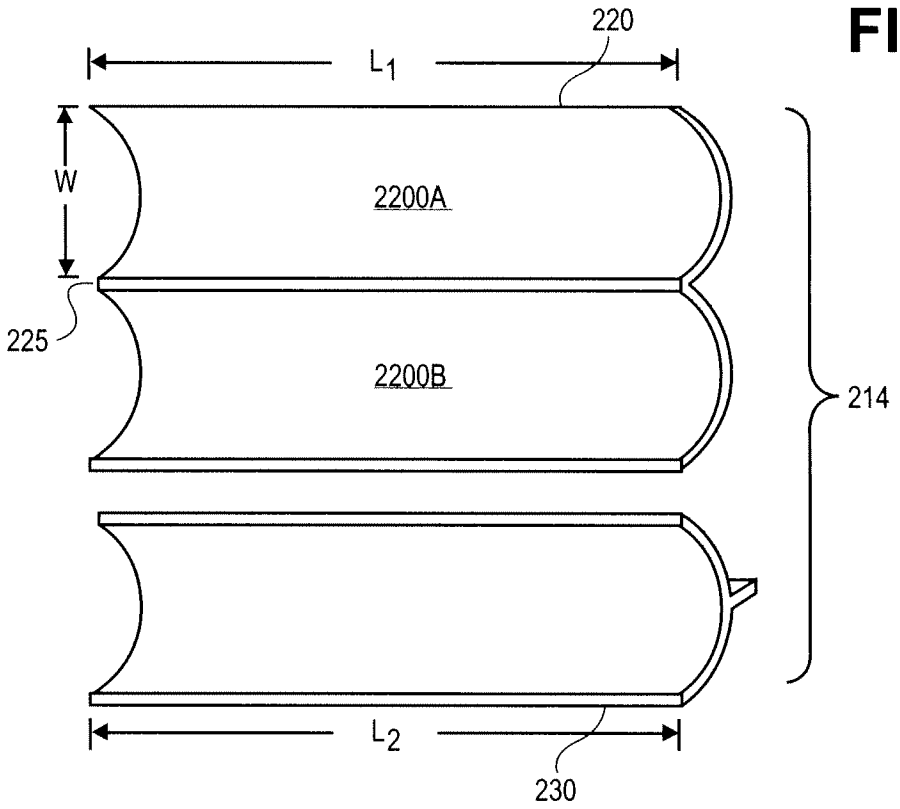


FIG. 1

FIG. 2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L_1
W
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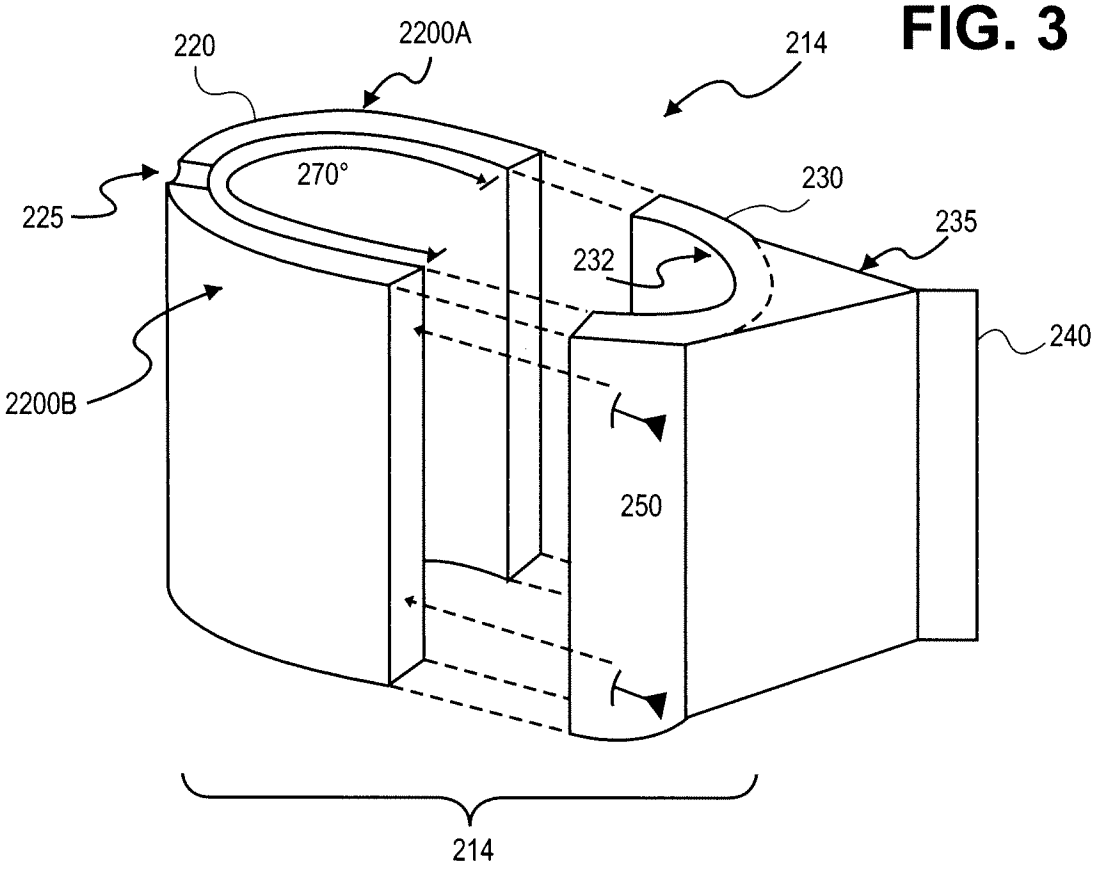
225
2200B
214
L_2
230

FIG. 3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2200A
214
270°
225
230
235
232
240
2200B
250
214

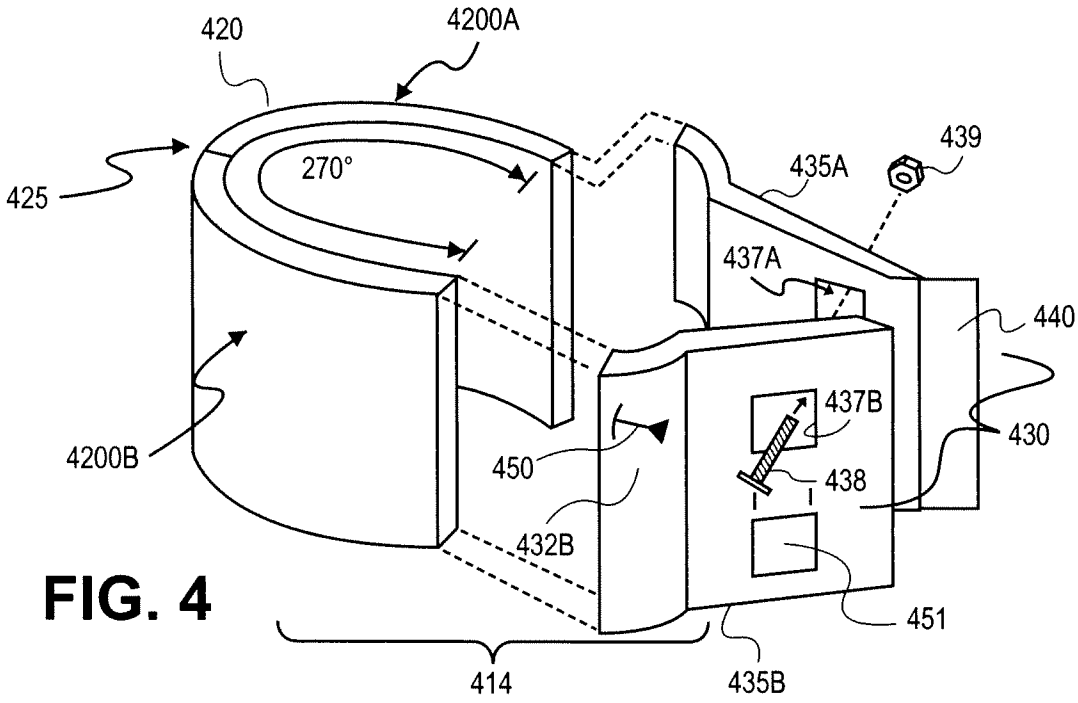
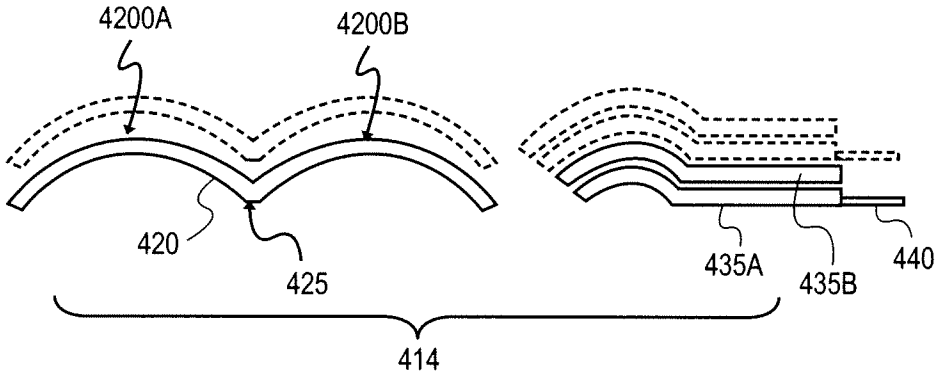

420
4200A
425
270°
439
435A
437A
440
437B
430
4200B
450
438
432B
451
414
435B

FIG. 4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4200B
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435A
435B
440
414

FIG. 5

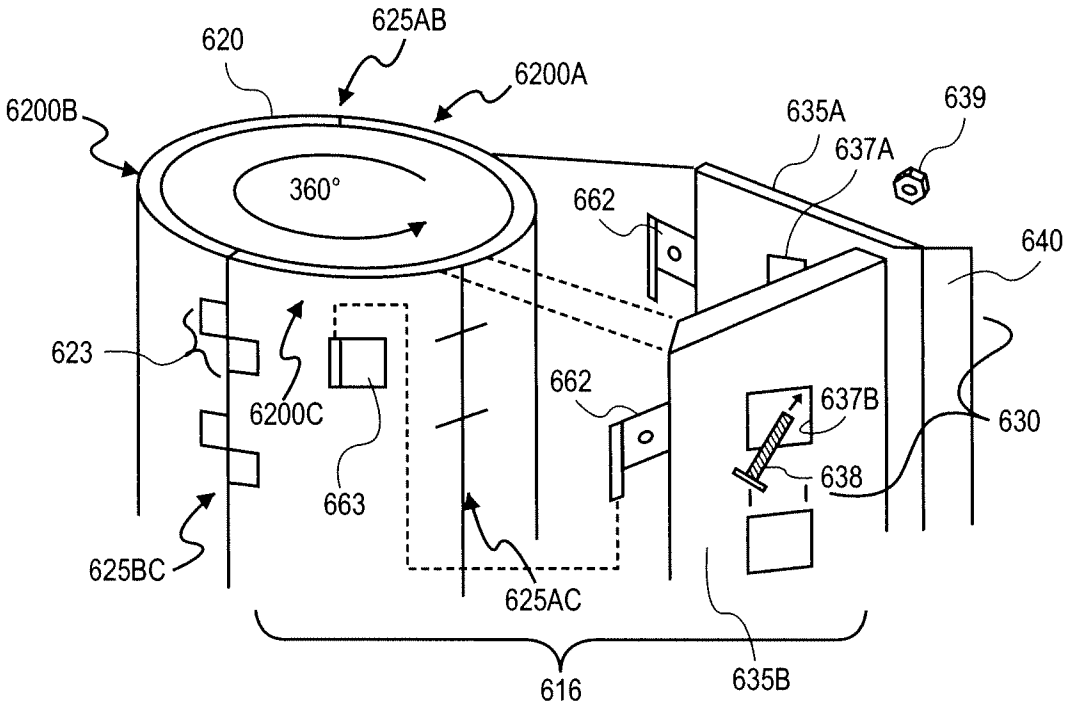
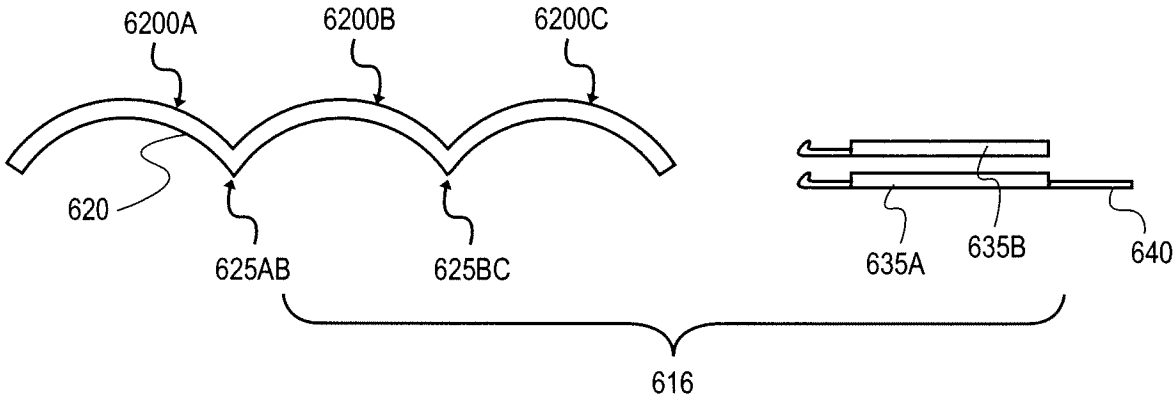

620
625AB
6200A
6200B
360°
635A
639
637A
662
640
623
6200C
662
637B
630
638
663
625BC
625AC
616
635B

FIG. 6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6200B
6200C
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625AB
625BC
635A
635B
640
616

FIG. 7

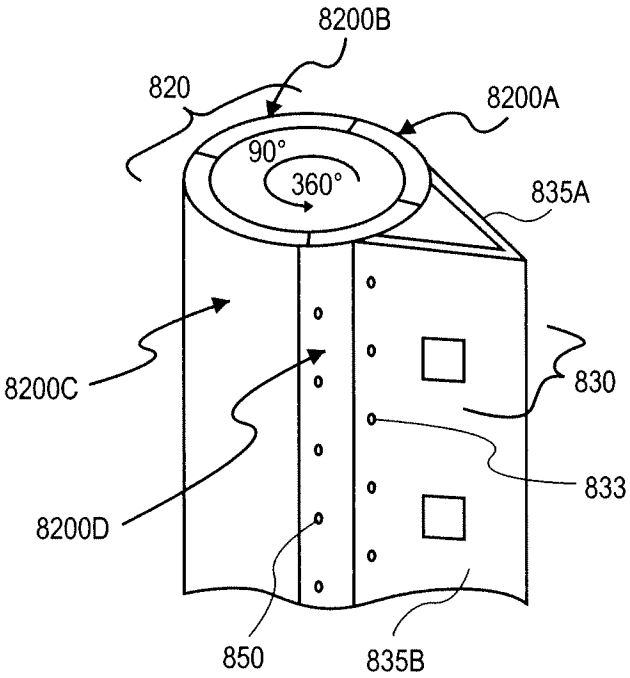
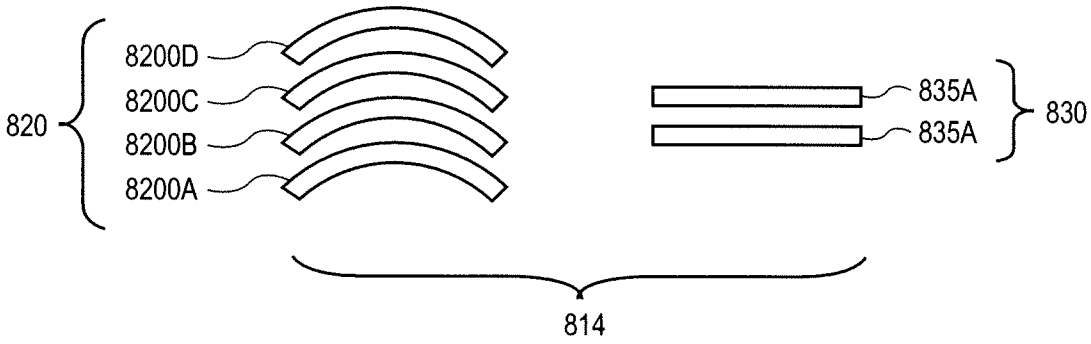

8200B
820
8200A
90°
360°
835A
8200C
830
833
8200D
850
835B

FIG. 8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8200D
8200C
8200B
8200A
835A
835A
830
814

FIG. 9

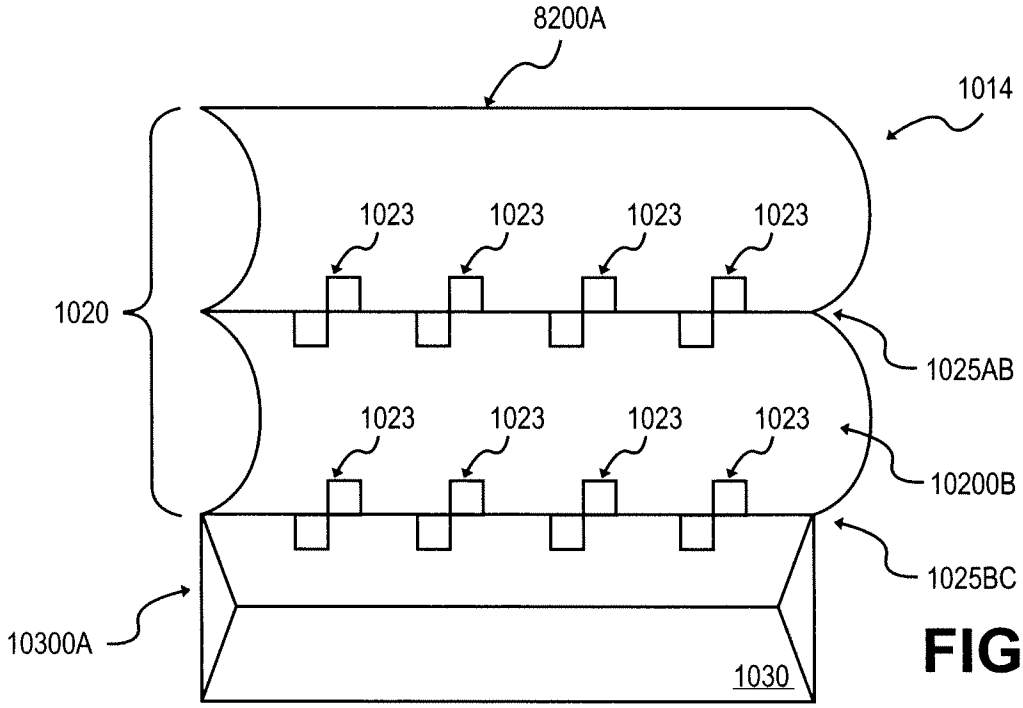
8200A
1014
1023
1023
1023
1023
1020
1025AB
1023
1023
1023
1023
10200B
1025BC
10300A
1030

FIG. 10

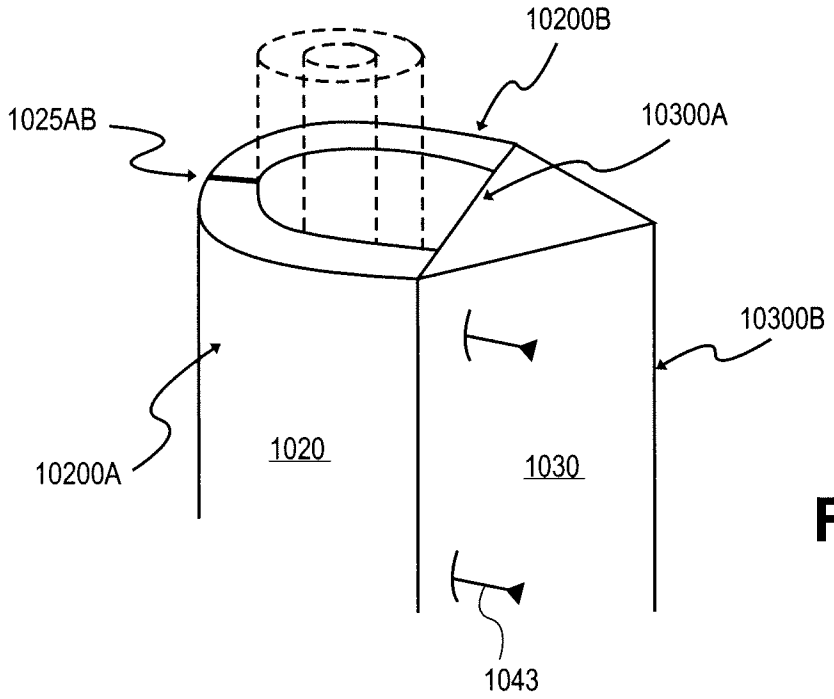
10200B
1025AB
10300A
10300B
10200A
1020
1030
1043

FIG. 11

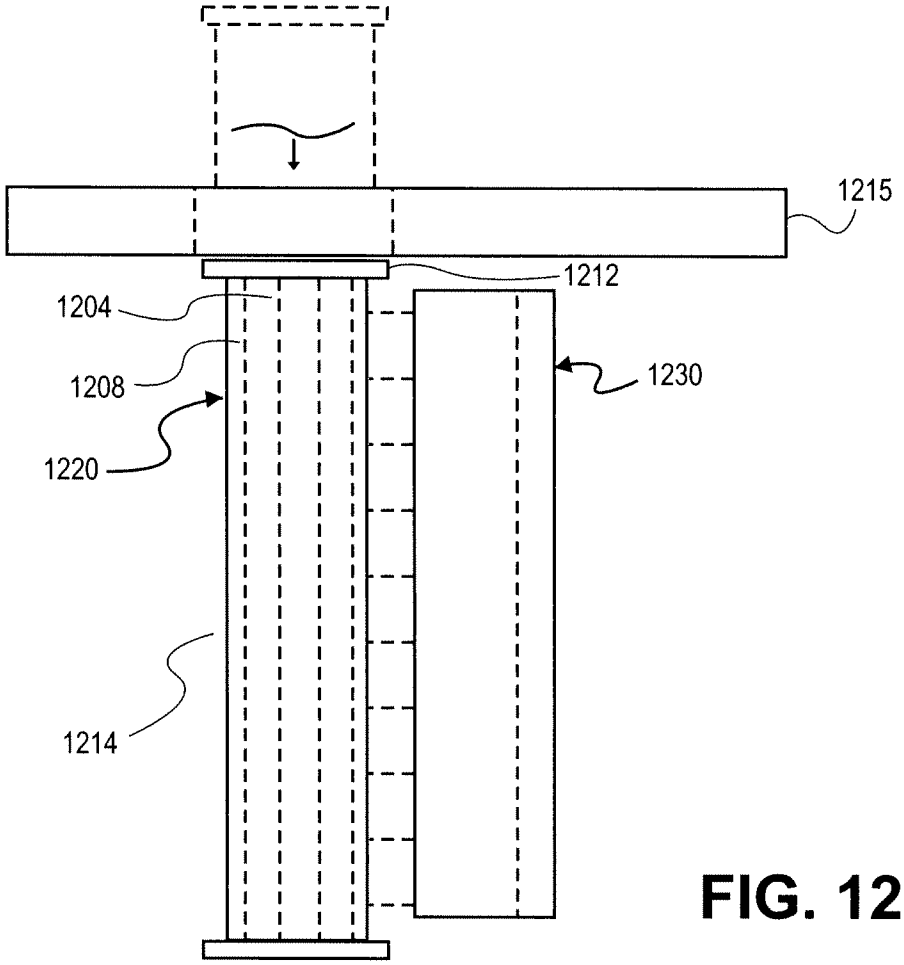

FIG. 12

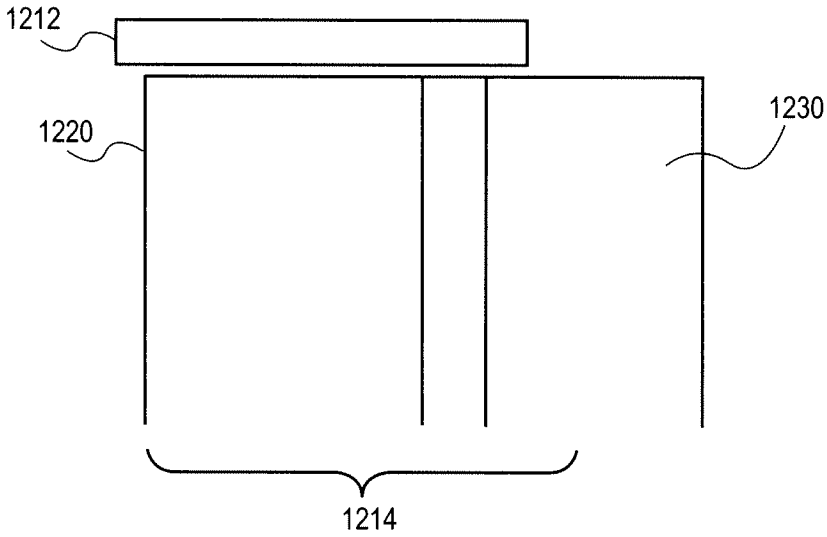

FIG. 13

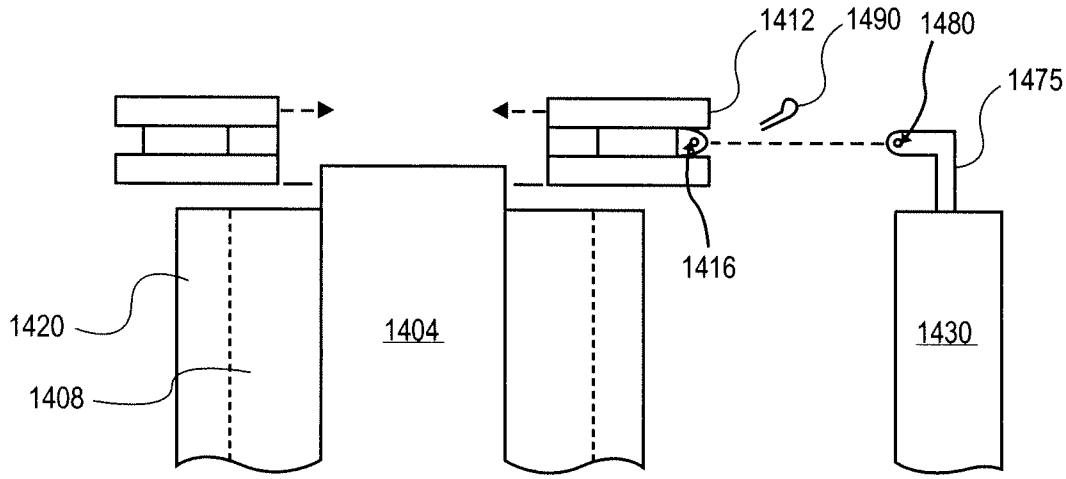

FIG. 14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 09/31446

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)
IPC(8) - E02D 5/60 (2009.01)
USPC - 405/211

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
IPC(8) - E02D 5/60 (2009.01)
USPC - 405/211; 405/195.1

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Electronic Databases Searched: Google Scholar; PubWest (US Patents full-text, US PGPubs full-text, EPO Abstracts, and JPO Abstracts) Search Terms Used: oil, petroleum, hydrocarbon, ocean, sea, platform, derrick, fairing, vibration, suppression, reduction, reduce, one, several, many, components, streamlined, teardrop

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6,517,289 B1 (COAKLEY et al.) 11 February 2003 (11.02.2003) entire document especially Fig. 1, Fig. 11, col 1, ln 8-12, col 2, ln 13-15, col 2, ln 16-23, col 3, ln 12-14, col. 3, ln 16-18, col 3, ln 22-24	1-2, 16-17
A	US 6,948,884 B2 (XU et al.) 27 September 2005 (27.09.2005)	1-2, 16-17
A	US 6,896,447 B1 (TAQUINO) 24 May 2005 (24.05.2005)	1-2, 16-17
A	US 6,223,672 B1 (ALLEN et al.) 1 May 2001 (01.05.2001)	1-2, 16-17
A	US 6,048,136 A (DENISON et al.) 11 April 2000 (11.04.2000)	1-2, 16-17

☐ 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	Date of mailing of the international search report
2 March 2009 (02.03.2009)	18 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

Form PCT/ISA/210 (second sheet) (April 2007)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 09/31446

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.: 3-15, 18-20
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.