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(54) Title: METHODS AND DEVICES FOR CLEANING SUBSEA STRUCTURES

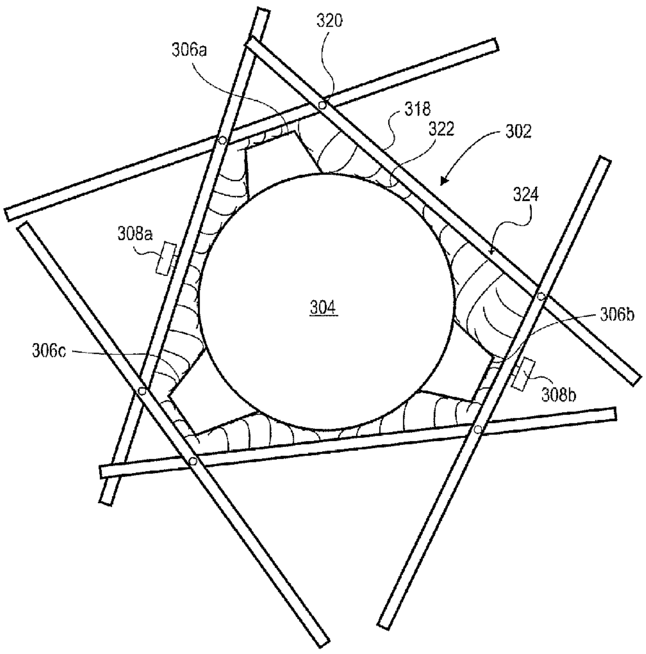


FIG. 3

(57) Abstract: A tool comprising a frame, and at least one cleaning device attached to the frame.

WO 2010/048039 A2

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# METHODS AND DEVICES FOR CLEANING SUBSEA STRUCTURES

## Field of the Invention

The present invention is directed to new and improved systems and methods for cleaning subsea structures.

## Background of the Invention

U.S. Patent Number 6,259,653 discloses a portable, diver-operated device that provides an improved method of cleaning surfaces underwater. The device includes a source of ultrasonic energy in a housing that has a compliant portion around an opening to engage and fit around a contaminated surface and clean it with the ultrasonic energy. The housing is made from material that diminishes transmission of the ultrasonic energy to ambient water. The compliant portion seals the source, the contaminated surface and some water from ambient water to concentrate the cleaning power of the source on the surface and to prevent transmission of harmful levels of energy outside of the device and through ambient water. U.S. Patent Number 6,259,653 is herein incorporated by reference in its entirety.

U.S. Patent Number 6,994,492 discloses methods for remotely installing vortex-induced vibration (VIV) reduction and drag reduction devices on elongated structures in flowing fluid environments. The devices installed can include clamshell-shaped strakes, shrouds, fairings, sleeves and flotation modules. U.S. Patent Number 6,994,492 is herein incorporated by reference in its entirety.

There is a need in the art for improved systems and methods to clean offshore structures. There is a need in the art for improved systems and methods to clean offshore structures without the use of divers. There is a need in the art for improved systems and methods to clean VIV suppression devices. There is a need in the art for higher efficiency systems and methods to clean offshore structures.

## Summary of the Invention

In one aspect, the invention provides a tool comprising a frame; and at least one cleaning device attached to the frame.

In another aspect, the invention provides a method of remotely cleaning a subsea structure, the method comprising positioning a tool adjacent to the subsea structure, wherein the tool comprises at least one cleaning device; moving the tool to position the tool around the subsea structure; closing the tool to a closed configuration to close the tool around the subsea structure, wherein the tool covers from about 10% to about 100% of the diameter of the subsea structure; and activating the cleaning device to clean the subsea structure.

Brief Description of the Figures

Figure 1 illustrates a sub sea system.

Figure 2a illustrates a side view of a cleaning device.

Figure 2b illustrates a top view of a cleaning unit of the cleaning device illustrated in Figure 2a.

Figure 2c illustrates a top view of a cleaning unit having a cleaning component attached thereto.

Figure 2d illustrates a top view of a cleaning unit having a cleaning component attached thereto.

Figure 2e illustrates a top view of a cleaning unit having a cleaning component attached thereto.

Figure 2f illustrates a top view of a cleaning unit having a cleaning component attached thereto.

Figure 2g illustrates a cross sectional view along line A-A' of the cleaning unit illustrated in Figure 2f.

Figure 3 illustrates a top view of a cleaning unit adjusted for cleaning of a tubular having strakes attached thereto.

Figure 4a illustrates a top view of a cleaning unit adjusted for cleaning of a tubular having a fairing attached thereto.

Figure 4b illustrates a top view of the cleaning unit of Figure 4a in a closed position.

Detailed Description

Figure 1:

Figure 1 illustrates an example of a subsea system. Subsea system 100 includes surface structure 101 near a water surface. Surface structure 101 is connected to subsurface structure 104 adjacent to seafloor 105 by tubular structure

102. In some embodiments, tubular structure 102 may be a riser. Exterior to tubular structure 102, there may be buoyancy material 103, such as foam, which may serve to insulate and/or provide buoyancy to tubular structure 102.

The sea has current 106, which may cause vortex-induced vibration (VIV) of tubular structure 102. To counter such VIV, one or more VIV suppression devices or structures may be installed along a length of tubular structure 102. In the illustration, fairings 108a, 108b, 108c and 108d are installed along a length of tubular structure 102. Fairings 108a, 108b, 108c and 108d may swivel around tubular structure 102 to counteract VIV. Collars 107a, 107b, 107c and 107d exterior to buoyancy material 103 are used to keep fairings 108a, 108b, 108c and 108d from moving along the length of tubular structure 102. In alternate embodiments, other suitable VIV suppression devices or structures, such as strakes, shrouds, wake splitters, or other VIV suppression devices or structures known in the arts, may be used in place of, or in addition to, one or more of the fairings, in order to help counter VIV.

Over time, the marine environment causes marine growth (e.g., rust, scale, slime, seaweed, algae, barnacles, and/or other plants and animals) on subsea components, such as collars 107a, 107b, 107c and 107d, fairings 108a, 108b, 108c and 108d, and other VIV suppression devices. This marine growth may tend to inhibit their VIV suppression performance. For example, excess marine growth may hinder or prevent rotation of fairings 108a, 108b, 108c and 108d. A non-rotating fairing subjected to a crosscurrent may result in vortex shredding, which may induce greater vibration than tubular structure 102 alone would induce. It is therefore advantageous to clean at least some of the components of subsea system 100 in order to help maintain their ability to suppress VIV.

Various techniques for cleaning subsea structures are disclosed in U.S. Patent Application Serial No. 61/106,832, entitled “METHODS AND DEVICES FOR CLEANING SUBSEA STRUCTURES”, having Attorney Docket Number TH3513, which is assigned to the same assignee, and is incorporated herein by reference in its entirety. There are potential benefits to developing new or different ways of cleaning subsea structures.

In accordance with various embodiments, ultrasound or ultrasonic waves may be used to clean subsea structures. Ultrasound generally refers to sound waves or pressures having a frequency higher than the threshold of human hearing, which varies from person to person. As used herein, for clarity, ultrasound refers to sound having a frequency greater than 15 kilohertz (kHz), and typically between 15 to 500 kHz.

Figure 2a:

Figure 2a illustrates a side view of a cleaning device. Cleaning device 200 includes frame member 202 and cleaning units 206a, 206b, 206c, 206d and 206e attached to frame member 202. Frame member 202 may include vertical members 208a and 208b and horizontal members 210a and 210b. Horizontal members 210a and 210b are, for example, dimensioned to extend around tubular 204 and/or any VIV suppression devices attached thereto. Horizontal members 210a and 210b provide structural support for the one or more cleaning units to be connected thereto. Vertical members 208a and 208b extend at least between horizontal members 210a and 210b and provide alignment support for any cleaning units connected between horizontal members 210a and 210b.

Although five cleaning units 206a, 206b, 206c, 206d and 206e are illustrated in Figure 2a, any number of cleaning units (for example, one or more) necessary for cleaning tubular 204 and any VIV suppression devices attached thereto may be attached to frame member 202. The cleaning units may be attached to frame member 202 by, for example, bolting the cleaning units to adjacent vertical members 208a and 208b. Cleaning units 206a, 206b, 206c, 206d and 206e are dimensioned to encircle the underlying tubular 204 and any VIV suppression devices mounted thereto. In this aspect, cleaning units 206a, 206b, 206c, 206d and 206e may be ring shaped structures which can be modified to accommodate the underlying structure to be cleaned. Cleaning units 206a, 206b, 206c, 206d and 206e may have the same or different cross sectional geometries. Representatively, where fairings are mounted to tubular 204, some of cleaning units 206a, 206b, 206c, 206d and 206e may be dimensioned to clean the fairing (e.g., pentagon shaped cross-section) while adjacent cleaning units are dimensioned to clean the underlying tubular (e.g., circular cross-section). Frame member 202 and cleaning units 206a, 206b, 206c, 206d and 206e may be made of a metal material such as aluminum or steel or any other similarly rigid material such as, for example, fiberglass or plastic.

Each of cleaning units 206a, 206b, 206c, 206d and 206e may include one or more cleaning components suitable for cleaning marine growth off an outer surface of the sub sea components around which they are positioned. The one or more cleaning components may be positioned along a surface of cleaning units 206a, 206b, 206c, 206d and 206e adjacent tubular 204. Suitable cleaning components may include, but are not limited to, bristles or brushes, water injection nozzles, scrapers, ultrasonic transducers, and/or cavitation cleaning devices (one suitable cavitation cleaning device is commercially available having the tradename Caviblaster from Cavidyne LLC of Gainesville, Florida, USA), or any other device which can suitably remove the targeted growth. In this aspect, cleaning device 200 may include a combination of cleaning units having the same or different cleaning components. Representatively, cleaning units 206a and 206c may include bristles or brushes, cleaning units 206b and 206d may include water injection nozzles and cleaning unit 206e may include scrapers or blades. In this aspect, the bristles may brush off marine growth attached to riser 204, water injection nozzles may be used to wash the growth brushed off tubular 204 away from tubular 204 and the scrapers may remove any marine growth not removed by the brushes and water injection nozzles.

The cleaning components may each protrude from surfaces of cleaning units 206a, 206b, 206c, 206d and 206e a similar distance or different distances. In still further embodiments, the cleaning components may be spring mounted to cleaning units 206a, 206b, 206c, 206d and 206e. In this aspect, cleaning device 200 can accommodate changes in cross sectional geometry through changes in the structure of cleaning units 206a, 206b, 206c, 206d and 206e as will be discussed more fully below, changes in the cleaning components or a combination of these changes.

In addition, it is contemplated that the cleaning components may be attached to vertical members 208a, 208b, horizontal members 210a and 210b or any other structure associated with cleaning device 200 that would facilitate cleaning of an underlying tubular or associated components (e.g. VIV suppression devices or collars).

In some embodiments, an optional weight 212 may be attached (e.g. bolted) to frame 202 to assist with lowering of cleaning device 200. Weight 212 may be attached to either a horizontal member similar to horizontal members 210a and 210b or ends of vertical members 208a and 208b opposite that of horizontal member 210a. Weight 212 may have any mass suitable for facilitating lowering of cleaning device 200 however not so great that it prevents rising of cleaning device 200. Weight 212 may be in the shape of a ring such that it fits around tubular 204 and evenly distributes weight about tubular 204. In still further embodiments, weight 212 may be of any size and dimensions and be made of any material suitable for attaching to frame 202. Representatively, weight 212 may be a steel ring or combination of steel blocks.

It is further contemplated that cleaning device 200 may include a buoyancy material (e.g. foam) to lighten the “in water” weight of cleaning device 200. Representatively, the buoyancy material may be attached to frame 202.

In some embodiments, an optional drive system may be attached (e.g. bolted) to frame 202 to assist with lowering and rising of cleaning device 200. The drive system may be in addition to weight 212, or weight 212 may be omitted. The drive system may include drive units 236a and 236b. Drive units 236a and 236b may include propellers having an axis parallel to that of tubular 204, or may have rollers that interface with tubular 204, or other drive mechanisms as are known in the art. Depending upon the direction in which the propellers and/or rollers are rotated, drive units 236a and 236b may be used to drive cleaning device 200 up or down a length of tubular 204. Representatively, when the propellers are rotated to expel water in a direction of the water surface, drive units 236a and 236b drive cleaning device 200 down tubular 204 toward the seafloor. Reversing the propellers drives cleaning device 200 up tubular 204 toward the water surface. It is further contemplated that in other embodiments, drive units 236a and 236b may include jet components such as water jets which emit a stream of liquid or gas from the nozzles to drive movement of cleaning device 200 along tubular 204.

Power may be supplied to drive units 236a and 236b by an umbilical 216 (e.g. power cord) extending from a power source (e.g. generator) on the surface structure. It is contemplated that drive units 236a and 236b may be electrically or hydraulically powered. It is further contemplated that drive units 236a and 236b may include a self contained power source, such as a battery, mounted to the unit. Operation of drive units 236a and 236b may be remotely controlled by a control unit at the surface structure. Alternatively, operation of drive units 236a and 236b may be controlled locally by, for example, a control unit at drive units 236a and 236b that may be operated by a remotely operated vehicle (ROV) or diver. Although two drive units 236a and 236b are illustrated in Figure 2a it is contemplated that any number of drive units suitable for raising and lowering cleaning device 200 may be used.

In another embodiment, one or more ballast tanks may be attached to frame 202 to assist with lowering and rising of cleaning device 200. The tanks may be flooded with water to assist in lowering cleaning device 200, and/or alternatively flooded with air or another suitable gas to assist in raising cleaning device 200. A gas tube may be connected to the tanks from the surface, or a pressurized gas tank may be provided adjacent the ballast tanks.

The positioning of cleaning device 200 about tubular 204 and any associated VIV suppression devices may be viewed using one or more underwater cameras, such as underwater camera 238. Camera 238 may be a still camera or a video camera such as those commonly used on ROVs. Camera 238 may include a light source to illuminate the structures to be viewed. Representatively, camera 238 may be a 0.5 lux low light high resolution black and white camera with two 100w lights. Alternatively, the light source may be separate from the camera and mounted to cleaning device 200. Representatively, incandescent lights, light-emitting diode (LED), high-intensity discharge (HID) or hydrargyrum medium-arc iodide (HMI) lights may be mounted to cleaning device 200. Images from camera 238 may be communicated to a monitor positioned on the surface structure or a vessel for viewing by a user. In this aspect, camera 238 and the monitor may be connected by any conventional sub sea cable capable of carrying video and data signals back and forth between camera 238 and the monitor or by any remote transmission means known to the art.. If a cable is used, it may be part of umbilical 216 described in more detail below.

It is further contemplated that other sensors may be used to identify structures (e.g. VIV suppresssion devices) mounted to the tubular. Representative other sensors may include, but are not limited to ultrasound, sonar, tactile, force feedback, or optical type or other subsea sensors as are known in the art.

In some embodiments, cleaning device 200 may be assembled by first selecting a suitable number and type of cleaning units 206a, 206b, 206c, 206d and 206e for cleaning the desired sub sea structure. Cleaning units 206a, 206b, 206c, 206d and 206e are adjusted to have a cross-section sufficient for cleaning the underlying structures (e.g. tubular and/or VIV suppression devices). Cleaning devices 206a, 206b, 206c, 206d and 206e, horizontal members 210a, 210b and optional weight 212 are then vertically aligned with one another. Vertical members 208a and 208b of frame member 202 may be attached (e.g. bolted) to cleaning units 206a, 206b, 206c, 206d and 206e, horizontal members 210a, 210b and optional weight 212 to maintain vertical alignment of each component. In some embodiments, vertical members 208a and 208b are, for example, rods having a length suitable for connecting to each of cleaning units 206a, 206b, 206c, 206d and 206e positioned one on top of the other as illustrated in Figure 2a. Vertical members 208a and 208b may be positioned on opposite sides of cleaning units 206a, 206b, 206c, 206d and 206e. Although two vertical members 208a and 208b are illustrated in Figure 2a, it is contemplated that any number of vertical members necessary to support the cleaning units that are to be used.

In some embodiments, horizontal members 210a and 210b are in the shape of a ring such that they encircle tubular 204 and hold vertical members 208a and 208b in position around tubular 204. In other embodiments, horizontal members 208a and 208b may be of any shape and dimension suitable to encircle tubular 204 and hold vertical members 208a and 208b in position. Although two horizontal members 210a and 210b are illustrated in Figure 2a, any number of horizontal members necessary to support vertical members 208a, 208b and cleaning units 206a, 206b, 206c, 206d and 206e attached thereto may be included in frame member 202. Representatively, weight 212 may be omitted and replaced with a third horizontal member to secure the bottom of cleaning device 200 or weight 212 may serve as both a weight and a securing device. Horizontal members 210a, 210b and vertical members 208a, 208b may be made of a metal material such as aluminum or steel or any other similarly rigid material such as, for example, fiberglass.

Cleaning device 200 may be assembled above the water or underwater using divers or an ROV. Representatively, above water installation may be achieved by assembling cleaning device 200 as described above around a top portion of tubular 204 or assembling cleaning device 200 separately and then inserting cleaning device 200 over an end of tubular 204. Once around tubular 204, device 200 may be lowered along a length of tubular 204 to the regions of tubular 204 and VIV suppression devices to be cleaned. For underwater installation, cleaning units 206a, 206b, 206c, 206d and 206e may be clam shell type structures meaning they can be opened and then closed around tubular 204. Representatively, cleaning units 206a, 206b, 206c, 206d and 206e may have a hinge on one side and an opening on an opposite side of the ring. A securing mechanism may be provided at the opening so that once cleaning units 206a, 206b, 206c, 206d and 206e are closed around tubular 204 the free ends may be secured in the closed position. Suitable securing mechanisms may include, for example, a serrated latch pin, clamp, bolt or any other type of closing mechanism suitable for holding ends of cleaning units 206a, 206b, 206c, 206d and 206e together and which may be operated by an ROV or diver. Exemplary hinge and latch type systems are disclosed in, for example, U.S. Patent No. 6,048,136, incorporated herein by reference in its entirety.

Winch lines 214a and 214b may be attached to frame 202 to assist with lowering and raising of cleaning device 200. Winch lines 214a and 214b may extend from a surface structure at a water surface and connect to frame 202. Winch lines 214a and 214b may be made of any material suitable for supporting cleaning device 200. Representatively, winch lines 214a and 214b may be made of any suitable natural or synthetic materials. In some embodiments, winch lines 214a and 214b may be made of steel. In other embodiments, winch lines 214a and 214b may be made of a metal or metal alloy that is resistant to extreme temperatures and corrosion (e.g. Inconel®, a nickel-based superalloy). Winch lines 214a and 214b may be wound around a spring mounted spool attached to the surface structure to control slack in winch lines 214a and 214b when cleaning device 200 is moved up and down along the structure being cleaned. In still further embodiments, other mechanisms and/or techniques may be used to control winch lines 214a and 214b. Although two winch lines 214a and 214b are illustrated in Figure 2a, it is contemplated that any number of winch lines suitable for raising and lowering cleaning device 200 may be used. In still further embodiments, winch lines 214a and 214b may be omitted all together and device 200 may be allowed to free fall to a desired location. Such an embodiment may be suitable where an ROV or diver is present to control cleaning device 200 underwater, or where an auotmatic ballasting system is employed.

It is further contemplated that in some embodiments, guide wheels or bearings may be attached to frame 202 or other portions of cleaning device 200 to guide cleaning device 200 along tubular 204 and any VIV suppression devices attached thereto. The wheels or bearings may be spring mounted to assist in navigation of cleaning device 200 along an underlying structure.

In some embodiments, umbilical 216 may extend from a surface structure at a water surface and connect to frame 202. Umbilical 216 may provide, for example, power, water, pressurized air, and/or hydraulic fluid to the cleaning units. In some embodiments, umbilical 216 may be a cable or group of cables that carry, for example, electrical power, pressurized air, hydraulic fluid, water, video and data signals back and forth between the surface structure and cleaning device 200. In some embodiments, umbilicals 216 may be attached to winch line 214 by, for example, bands, clamps or by helically wrapping the additional lines around winch line 214.

Optional guide members 240a and 240b may be connected to and extend from a bottom or top end of cleaning device 200. Guide members 240a and 240b may facilitate aligning of cleaning device 200 with structures to be cleaned or rotate, for example fairings, to align with cleaning device 200. In some embodiments, guide members 240a and 240b are attached to weight 212. In other embodiments, where weight 212 is omitted, guide members 240a and 240b may be attached to a horizontal member similar to horizontal member 210a positioned at a bottom of cleaning device 200. In some embodiments, the horizontal member at the bottom of cleaning device 200 is a rotating ring. The ring rotates as fairings are encountered and aligns the fairings with device 200. In some embodiments, rotation of the ring is controlled at the surface by a control system. In other embodiments, alignment is done by orienting guide members 240a and 240b around or adjacent to the structure to be cleaned (e.g., fairing) by rotating device 200 until the structure is aligned as desired.

Guide members 240a and 240b may be substantially straight with outwardly curved ends. The curved ends may be used to tap and rotate a fairing or other structure until it is aligned with an adjacent cleaning unit (e.g. cleaning unit 206e) of device 200 or rotate cleaning device 200 to align the device with the fairing or other structure. In this aspect, when the cleaning unit is inserted around, for example, the fairing, the fairing is properly positioned within the cleaning unit. Guide members 240a and 240b may have a wire-like structure or any other structure suitable for aligning the structures to be cleaned.

Guide members 240a and 240b may be made of a metal material, such as aluminum, steel or copper, a plastic material, a fiberglass material or any other similar material suitable for aligning a non-cylindrical VIV suppression device with cleaning device 200. It is contemplated that guide members 240a and 240b may be integrally formed with the horizontal member or weight 212 or attached by, for example, bolting or fusing (e.g., welding) them to the desired structure. Although two guide members 240a and 240b are described, additional guide members may be provided. Representatively, a first set of guide members 240a and 240b may extend from a bottom of cleaning device 200 and a second set of guide members may extend from a top of cleaning device 200 to provide additional guidance.

In each of the embodiments disclosed herein, cleaning is accomplished by moving and/or rotating cleaning device 200 along the length of tubular 204 having VIV suppression devices attached thereto using winch lines, an ROV and/or a diver. The cleaning device is designed for multiple passes along the tubular and associated VIV suppression devices. In this aspect, the cleaning device may be rotated for successive passes or adjusted and/or modified between successive passes.

In some embodiments where cleaning device 200 is rotated along the length of tubular 204, for example where strakes are attached to tubular 204, umbilical 216 or winch lines 214a and 214b attached to cleaning device 200 may become tangled. To prevent tangling, in some embodiments, cleaning device 200 may rotate within a non-rotating housing and umbilical 216 and winch lines 214a and 214b may be connected to the non-rotating housing. As the non-rotating housing is moved down a length of tubular 204, cleaning device 200 rotates within the housing. Since umbilical 216 and winch lines 214a and 214b are connected to the non-rotating housing, rotation of umbilical 216 and winch lines 214a and 214b around tubular 204 is prevented. In this aspect, the ROV need only move the housing up or down the tubular and does not need to rotate around the tubular along with cleaning device 200. The housing may have a substantially cylindrical shape dimensioned to fit around cleaning device 200. The housing may be made of the same or different material to that of cleaning device 200. Representatively, the housing may be made of a metal or fiberglass material.

In still further embodiments, umbilical 216 and winch lines 214a and 214b may be attached to a non-rotating ring rotatably coupled to cleaning device 200. In this embodiment, umbilical 216 and winch lines 214a and 214b are attached to the ring. The ROV need only move the ring up or down the tubular and cleaning device 200 rotatably attached thereto will rotate along the strakes as it is moved along the length of the tubular. In some embodiments, a rotary transformer may be used to allow power to be transferred between rotating device 200 and an umbilical supplying power thereto which is attached to the non-rotating housing or ring.

Although a non-rotating housing and non-rotating ring are described, it is further contemplated that any mechanism suitable for allowing for rotation of cleaning device 200 without tangling umbilical 216 and winch lines 214a and 214b may be used.

Figure 2b-2g:

Figure 2b illustrates a top view of a cleaning unit, like the cleaning device illustrated in Figure 2a. Cleaning unit 206 may be formed by links 218 attached to one another at their ends by connectors 220. Cleaning components such as bristles 222, water outlets/nozzles 226,228 and scrapers 234 illustrated in Figures 2c, 2d, 2e and 2f may be attached to links 218 as will be discussed in more detail below. The basic link and connector structure described in reference to cleaning unit 206 may be used for cleaning units 206a, 206b, 206c, 206d and 206e.

Links 218 may be elongated structures which, when attached at their ends, fit around a riser or VIV suppression device. Although links 218 are illustrated in Figure 2b as elongated rectangular structures with a length and width dimension as illustrated, it is contemplated that links 218 may be slightly curved or have another shape which allows them to conform to the surface dimensions of the structure to be cleaned. A height dimension (not shown) of each of links 218 may be selected to be that which is necessary to accommodate the cleaning component(s) to be connected to links 218 or may be selected to accommodate rows of cleaning components. In some embodiments, the height may be equivalent to a height dimension of a tubular or a VIV suppression device. In other embodiments, each of links may have a height less than that of a VIV suppression device such that when multiple cleaning units are included in cleaning device 200, cleaning device 200 has a height equivalent to or less than a height dimension of the VIV suppression device.

In some embodiments, links 218 may be fixedly attached to one another at connectors 220. In this aspect, links 218 may be solid structures having holes formed through each end for insertion of connectors 220. Representatively, where cleaning unit 206 is to be used with structures of the same shape, it may be desirable for cleaning unit 206 to have a fixed shape. In this aspect, connectors 220 may be bolts which are inserted through adjacent links 218. Once a desired shape of cleaning unit 206 is achieved, the bolts are tightened to prevent movement of links 218 with respect to one another.

In other embodiments, links 218 may be slidably attached to one another. In this aspect, links 218 may have a channel or opening along the length dimension. Figure 2b illustrates links 218 having opening 224 formed therein. Connectors 220 may be inserted through portions of opening 224 of adjacent links 218 near the ends of links 218. Connectors 220 may be bolts, screws or pins which fit within opening 224 and have components at ends extending beyond links 218 which are larger than a width of links 218 so that connectors 220 do not slide through the link openings. Representatively, connectors 220 may be bolts, screws or pins having a head at one end and a nut attached to the opposite end or no head and nuts attached to both ends, or head at one end and a crosspin at the other end, or crosspins at both ends, or a nut at one end and a crosspin at the other end. Connectors 220 may slidably connect links 218 together to allow the shape of cleaning unit 206 to be modified.

Although openings 224 are illustrated in Figure 2b, it is further contemplated that channels which allow connectors 220 to slide therein may be formed in links 218 instead of openings 224. In this aspect, links 218 may be substantially solid structures having channels formed within interfacing sides of adjacent links 218. Ends of connectors 220 may be received within the channels of adjacent links 218 and can slide along the channels to allow the shape of cleaning unit 206 to be adjusted. Representatively, the channels may be “T” shaped channels and connectors 220 may be nut and bolt type connectors. A nut may be positioned at each end of links 218 within the widest portion of the “T” shaped channel. A bolt shaft without a cap portion may be inserted within the opening of the channels of adjacent links 218 and rotated to insert the bolt through each of the nuts. The bolt with nuts attached to each end may then slide within the channel to slide one or both of the adjacent links with respect to each other. Although a nut and bolt type of connector and “T” shaped channel are described above, it is further contemplated that any type of channel and connector system suitable for allowing links 218 to slide with respect to one another may be used.

Each of links 218 may include at least one hydraulic cylinder 242a for adjusting links 218. In Figure 2b, hydraulic cylinders 242a and 242b are shown at opposite ends of one of links 218. When cleaning device 200 is lowered down the tubular, it may encounter an appurtenance that has a cross sectional geometry significantly different from the rest of the tubular (e.g. a fairing). The tool assembly must be able to accommodate the appurtenance as it travels along the length of the tubular in order to successfully clean the tubular and associated VIV suppression devices. In this aspect, hydraulic cylinders 242a and 242b are mounted to each of links 218 so that the cross sectional geometry of cleaning unit 206 can be modified as it encounters structures of different shapes and sizes. One or more cameras mounted to cleaning device 200 as previously discussed may be used to assist in detection of the different structures and to modify cleaning unit 206 to the desired shape.

Hydraulic cylinders 242a and 242b include cylinder barrels 244a and 244b and piston rods 246a and 246b, respectively. Cylinder barrels 244a and 244b are secured to opposite ends of one of links 218. Piston rods 246a and 246b extend from barrels 244a and 244b, respectively, and are connected to connectors 220. In this aspect, when piston rods 246a and 246b are extended outside of barrels 244a and 244b, respectively, a distance between the ends of link 218 and connectors 220 connected to piston rods 246a and 246b at each end is increased. This, in turn, shortens a length of link 218 between connectors 220 and draws links adjacent to link 218 toward one another. Piston rods 246a and 246b may further be retracted into barrels 244a and 244b, respectively, to increase the length of link 218 between connectors 220 at each and thereby increase a length of the side of cleaning unit 206.

In some embodiments, hydraulic cylinders 242a and 242b may remain in the expanded or retracted configuration to hold links 218 in place. In other embodiments, notches 248 may be formed within portions of links 218 adjacent connectors 220 to hold links 218 in place. Representatively, notches 248 may be formed by a series of protrusions 250 extending from inner surfaces of links 218 with gaps 252 in between ends of each protrusion. Connectors 220 may be held between adjacent protrusions until a force is applied by, for example, hydraulic cylinders 242a and 242b. Once a force is applied, each of the connectors 220 are advanced through the nearest gap and in between the next set of protrusions. Although hydraulic cylinders 242a and 242b are illustrated at each end of links 218, they need not be operated at the same time. For example, the shape of cleaning unit 206 may be modified by adjusting only one of the hydraulic cylinders at a time. Although hydraulic cylinders 242a and 242b are illustrated and described, other types of actuators would be suitable, for example electric linear gear motor actuators, magnetic linear motors, or other suitable means to move connectors 220.

Hydraulic lines, or other types of lines, for operating hydraulic cylinders 242a and 242b may be carried by umbilical 216 extending from a surface structure to cleaning device 200. The hydraulic fluid may be pressurized using a pump attached to device 200 or the surface structure.

Although the hydraulic cylinders and associated components are only illustrated with respect to one link, it is contemplated that each of the eight links 218 shown in Figure 2b include hydraulic cylinders and, in some embodiments, notches as described above.

It is further contemplated that in some embodiments, springs may be included between adjacent links 218 to better accommodate diameter changes and appurtenances along the tubular.

Vertical members 208a and 208b are further illustrated in Figure 2b attached (e.g. bolted) to the outer surfaces of links 218.

The number and dimensions of links 218 may vary depending upon the shape and size of the structure to be cleaned. Representatively, any number of links 218 suitable for forming cleaning units 206 having an inner surface which substantially conforms to an outer surface of the structure to be cleaned may be used. Representatively, where the structure to be cleaned has a cylindrical outer surface, cleaning unit 206 may have eight links 218 attached to one another as shown in Figure 2b.

Cleaning unit 206 may be installed on a tubular above the water surface or underwater as previously discussed. For underwater installation, cleaning unit 206 may have a hinge and securing mechanism (e.g. a latch) replacing oppositely positioned connectors 220 to allow cleaning unit 206 to be opened and closed underwater. Once a desired number of cleaning units 206 are positioned around a tubular, vertical members 208a and 208b may be secured to the cleaning units. In addition, although not shown, horizontal members such as horizontal members 210a and 210b may further be attached to vertical members 208a and 208b to provide added support to the structure.

Figure 2c illustrates a top view of a cleaning unit having bristles. The cleaning unit may be cleaning unit 206a illustrated in Figure 2a. Cleaning unit 206a may be substantially similar to cleaning unit 206 described in reference to Figure 2b. In this aspect, cleaning unit 206a may be formed by links 218 attached to one another at their ends by connectors 220. Although, not shown, hydraulic cylinders, or other actuators, may be attached to links 218 as discussed in reference to Figure 2b to facilitate adjustment of cleaning unit 206b. Cleaning components 222 may be attached to a surface of each of links 218 to clean a tubular structure (e.g. riser) or VIV suppression device (e.g. smooth sleeve) around which cleaning unit 206a is positioned. In this embodiment, cleaning components 222 are bristles.

Bristles 222 are attached to links 218 to clean a structure around which cleaning unit 206a is positioned. In this aspect, bristles 222 may have any length suitable for contacting and cleaning marine growth from a structure around which cleaning unit 206a is positioned. Bristles 222 may be made of any material suitable for cleaning marine growth from a sub sea device when passed along a surface of the device. Representatively, bristles 222 may be made of a plastic or metal material. Representatively, bristles 222 may be polyester bristles or steel wire bristles. In still further embodiments, bristles 222 may be replaced with metal bolts for removing the more difficult to remove types of marine growth such as heavy shell growth. Bristles 222 may be attached to links 218 by any suitable connecting mechanism. Representatively, bristles 222 may be anchored in superficial holes along links 218 by, for example, inserting barbed ends of bristles 222 into the holes. Once within the holes, the barbed ends expand beneath the surface of links 218 and hold bristles 222 thereto. Alternatively, bristles 222 may be attached to the surface of links 218 by, for example, soldering metal bristles 222 to the surface of metal links 218. Bristles 222 may extend perpendicular to the surface of links 218 or be angled to provide improved cleaning performance.

Bristles 222 may be randomly positioned along links 218 or in columns, rows or any other similarly suitable pattern for cleaning an underlying device. Although bristles 222 are shown extending from an inner surface of links 218 in Figure 2b, it is further contemplated that where cleaning unit 206a is at an end of a cleaning device adjacent to, for example, a collar, bristles may extend from an upper edge of links 218 to further clean a collar positioned above the device. In still further embodiments, bristles 222 may be positioned along links 218 in groups as will be discussed in more detail in reference to Figure 2d below.

It is further contemplated that in some embodiments, cleaning unit 206a, and in turn bristles 222, may be vibrated to facilitate cleaning of a desired structure. A cam device or other suitable devices may be used to vibrate links 218 and/or bristles 222. Although a cam device is described, it is further contemplated that any type of actuators and drive systems may be used to vibrate cleaning unit 206a.

Vertical members 208a and 208b may be attached to an outer surface of cleaning unit 206a and any cleaning units positioned above or below cleaning unit 206a (e.g. 206b, 206c, 206d and 206e) to hold the cleaning units in a desired position with respect to one another.

Figure 2d illustrates cleaning unit 206a of Figure 2c having groups of bristles. In this embodiment, bristles 222 are grouped to form brush 264 connected to links 218 by support arm 266. Brush 264 may be substantially the same as, for example, those available commercially from U.M.C. International Plc of the United Kingdom under model numbers 01212, 01202, 01114 and 01102. In some embodiments, support arm 266 is a spring jointed arm as illustrated in Figure 2d such that brush 264 is extended from or contracted toward the associated link depending upon the distance of the surface of tubular 204 from link 218. In one embodiment, brush 264 is biased towards structure 204 by one or more springs or other biasing devices. It is contemplated that brushes 264 may protrude from surfaces of links 218 the same distance or different distances. In this aspect, cleaning device 200 can accommodate changes in cross sectional geometry through changes in the assembly of links 218 or changes in the length of brushes 264 or a combination of these changes. In some embodiments, brush 264 may be connected to a motor (not shown) which will rotate brush 264 to increase cleaning effectiveness. The motor may be an electric, pneumatic, or hydraulic motor that may be powered by power cables included in umbilical 216, or by local, included sources, such as fuel cells, batteries, compressed gas tanks, or other sources. Suitable motors may be those available commercially from, for example, Armada Systems Inc. of Pensacola, Florida.

In still further embodiments, groups of bristles 222 may extend from support disks rotably connected directly to an inner surface of links 218. Groups of bristles 222 and the associated disks may be randomly positioned along the surface of links 218 or in a pattern (e.g. rows, columns, etc.). The disks may be rotably connected to links 218 by, for example, pins through links 218 and an opening in the center of each of the disks. As cleaning unit 206a is moved over a surface of, for example, a tubular, the friction on bristles 222 causes bristles 222 coupled to the disks to rotate. In still further embodiments, rotation of the disks having bristles 222 attached thereto may be controlled by, for example, an electric or hydraulic motor assembly coupled to the disks.

Figure 2e illustrates a top view of a cleaning unit having water jets. The cleaning unit may be cleaning unit 206b illustrated in Figure 2a. Cleaning unit 206b may have substantially the same structure as cleaning unit 206 discussed in reference to Figure 2b except that water outlets 226 are provided along an inner surface of links 218. Cleaning unit 206b includes links 218 attached to one another by connectors 220. Openings 224 or channels may be formed within links 218 to allow for adjustment of links 218. Although, not shown, hydraulic cylinders, or other types of actuators, may be attached to links 218 as discussed in reference to Figure 2b to facilitate adjustment of cleaning unit 206b. Vertical members 208a and 208b are further connected to links 218 to hold cleaning unit 206b in a desired position with respect to neighboring cleaning units (e.g. cleaning units 206a, 206c, 206d and 206e).

Water outlets 226 may be provided in addition to or in place of bristles. In embodiments where both water outlets 226 and bristles are used, bristles may extend from portions of links 218 between outlets 226. Water outlets 226 may be openings formed through an inner surface of links 218. Nozzles 228 are mounted around each outlet 226 to regulate fluid flow. During cleaning, one suitable distance between nozzles 228 and the surface to be cleaned is from 1 to 20 cm, for example from 2 to 10 cm. In some embodiments, nozzles 228 are spring mounted to better accommodate diameter changes and appurtenances along tubular 204.

Nozzles 228 may be dimensioned to discharge a fluid at a sufficient rate to clean marine growth off of the surface of a structure (e.g. a VIV suppression device) around which cleaning unit 206b is positioned without damaging the structure or any coating included on the surface. In one example, 3000 pounds per square inch (psi) of water may be released through a 0.5 inch diameter nozzle 228 at a flow rate of about 14 gallons per minute (gpm) to clean the underlying tubular and/or VIV suppression device. In some embodiments, nozzles 228 may be self-resonating pulsed water jets which allow a constant flow rate pump to provide pulsed output jets. Cleaning unit 206b may be rotated or moved up and down tubular 204 during cleaning. In addition to cleaning the underlying device, fluid flowing from water outlets 226 and nozzles 228 may help to remove marine growth which may collect between cleaning unit 206b and the structure during cleaning. It is further contemplated that outlets 226 and nozzles 228 may be positioned along upper or lower edges of links 218 where cleaning of structures above or below cleaning unit 206b are desired.

Water may be delivered from surface structure 102 described in reference to Figure 1 to water outlets 226 and out nozzles 228 via conduit 230. Conduit 230 may be, for example, high-pressure tubing, which extends from surface structure 102. In some embodiments, conduit 230 terminates within a fluid receiving manifold 232 adjacent outlets 226. Fluid receiving manifold 232 may be dimensioned to receive fluid from conduit 230 and then allow the fluid to be distributed to each of outlets 226 and out nozzles 228. In this aspect, fluid receiving manifold 232 may have a closed side having only an opening for receiving an end of conduit 230 and an open side positioned around each of outlets 226. Fluid receivingmanifold 232 may be formed within links 218 in the case of solid links or may be a separate structure mounted to a surface of links 218 in the case of open links such as those illustrated in Figure 2e. It is noted that regardless of the specific structure of fluid receiving manifold 232 it should be dimensioned so as not to interfere with movement of links 218 as previously discussed. In other embodiments, a plurality of conduits 230 which terminate at each of nozzles 228 may be used and receiving manifold 232 omitted. Alternatively, any type of system and structure suitable for emitting a fluid from links 218 to clean an underlying structure may be used.

A pump mechanism (not shown) may be provided on surface structure 102 to pump water from a water source on the surface structure or directly from the sea and through conduit 230 to nozzles 228. The pump mechanism may be any suitable pumping mechanism capable of pumping water through conduit 230 to nozzles 228. Alternatively, a pump mechanism may be attached directly to cleaning unit 206b which may pump water into conduit 230 and out nozzles 228 of cleaning unit 206b.

Figure 2f illustrates a top view of a cleaning unit having scrapers. The cleaning unit may be cleaning unit 206e illustrated in Figure 2a. Cleaning unit 206e may have substantially the same structure as cleaning unit 206 discussed in reference to Figure 2b except that scrapers 234 are provided along an inner surface of links 218. Cleaning unit 206e includes links 218 attached to one another by connectors 220. Openings 224 or channels may be formed within links 218 and hydraulic cylinders, or other types of actuators, connected thereto to allow for adjustment of links 218. Vertical members 208a and 208b are further connected to links 218 to hold cleaning unit 206e in a desired position with respect to neighboring cleaning units (e.g. cleaning units 206a, 206b, 206c and 206d).

Scrapers 234 may extend from links 218 to form an acute angle with respect to the surface of links 218. Scrapers 234 may be attached to links 218 by, for example, a hinge and spring mechanism, so that scrapers 234 may adjust along the contours of the device being cleaned. Tensioning devices may further be provided between links 218 and scrapers 234 to bias scrapers 234 in a direction of the tubular and/or VIV suppression devices cleaning (see Figure 2g). Representatively, as cleaning unit 206e is moved down a length of, for example, a tubular having fairings and collars attached thereto, scrapers 234 can pivot with respect to links 218 and adjust according to the changing surface dimensions thereby scraping marine growth from a surface of each structure.

Scrapers 234 may be made of any size and shape suitable for scraping marine growth off the side of a sub sea structure (e.g. tubular or VIV suppression device). Representatively, scrapers 234 may be elongated rectangular members as illustrated in Figure 2f or may be curved along the length or end or barbed at the end to provide additional scraping capabilities. Scrapers 234 may be made of any rigid material suitable for scraping marine growth off a sub sea structure. Suitable materials may include, but are not limited to metal such as steel or aluminum, a plastic material or fiberglass.

Figure 2g illustrates a cross sectional view along line A-A' of cleaning unit 206e illustrated in Figure 2f. One of scrapers 234 is shown extending from links 218 to form an acute angle with respect to the surface of links 218. Tensioning device 260 is further shown positioned between link 218 and scraper 234 to bias scraper 234 against the structure to be cleaned. In this aspect, when cleaning device 206e is moved down the structure to be cleaned in the direction of arrow 262, marine growth attached to the structure is scraped off by scraper 234 positioned along a surface of the structure. In some embodiments, barbs (not shown) may further extend from ends of scrapers 234 to provide added cleaning capabilities.

In some embodiments, a sole cleaning mechanism may be used to clean subsea structures. In other embodiments, one or more additional cleaning mechanisms, in addition, may optionally be used for cleaning subsea structures. For example, bristles, brushes, rotating brushes, water jets, scrapers, barbed scrapers, ultrasonic sources, and/or combinations thereof, may also optionally be used for cleaning subsea structures. U.S. Patent Application Serial No. 61/106,832, having attorney docket number TH3513, shows various ways for employing other types of cleaning mechanisms.

Figure 3:

Figure 3 illustrates a top view of a cleaning unit adjusted for cleaning of a tubular having strakes attached thereto. Cleaning unit 302 includes links 318 attached at their ends with connectors 320. Links 318 and connectors 320 may be substantially similar to links 218 and connectors 220 discussed in reference to Figures 2b, 2c, 2d, 2e and 2f. Bristles 322 similar to those previously discussed in reference to Figure 2c or 2d may be attached to links 318. Although bristles 322 are illustrated in Figure 3, it is contemplated that any one or a combination of the cleaning components previously discussed in reference to Figures 2c, 2d, 2e and 2f (e.g. brushes, water jets and/or scrapers) may be included in cleaning unit 302 to facilitate cleaning of the underlying structure. Although, not shown, hydraulic cylinders, or other types of actuators, may be attached to links 318 as discussed in reference to Figure 2b to facilitate adjustment of cleaning unit 302.

Six links 318 adjusted to clean an underlying tubular 304 having helical strakes 306a, 306b and 306c attached thereto are illustrated in Figure 3. Strakes 306a, 306b and 306c may have any shape and dimensions (e.g. a polygon shaped or round profile) and be mounted to tubular 304 in any manner suitable for suppressing VIV about tubular 304. Representatively, strakes 306a, 306b and 306c may be substantially similar to, for example, those disclosed in U.S. Patent Application Publication No. 2006/0280559, which is herein incorporated by reference in its entirety.

Although three strakes 306a, 306b and 306c are illustrated in Figure 3, it is contemplated that any number of strakes suitable for reducing VIV about tubular 304 may be used, for example, from two to six strakes. The shape of cleaning unit 302 and the number of links 318 and associated connectors 320 may further be modified depending upon the number of strakes. Representatively, where three strakes 306a, 306b and 306c are mounted to tubular 304, six links 318 may be positioned in a substantially hexagrammic shape with disjointed vertices forming an interor that is substantially triangular with truncated vertices, to conform to the outer surface of the underlying structure. In other embodiments, where, for example, six strakes are mounted to tubular 304, cleaning unit 302 may further include six links 318 but the length of links 318 between connectors 320 may be substantially equal and each corner formed by links 318 may be positioned at each of links 318. It is contemplated that any arrangement of links 318 may be suitable for cleaning strakes so long as portions of links 318 (e.g. corners) align with the strake fins to ensure rotation of cleaning unit 302 along the tubular.

Vertical members 308a and 308b are connected to links 318 to hold cleaning unit 302 in a desired position with respect to other cleaning units positioned above or below cleaning unit 302. It is contemplated that the other cleaning units may have the same or different shape and the same or different type of cleaning component as cleaning unit 302.

Figure 3 represents a somewhat generalized form of cleaning unit 302. In practice, the body of cleaning unit 302 may take various different physical forms or configurations in various embodiments. Aforementioned U.S. Patent Application Serial No. 61/106,832, having attorney docket number TH3513, discloses a number of suitable physical forms or configurations. One suitable configuration involves the body having a support unit that may be lowered from a platform and controlled or remotely operated by a remotely operated vehicle (ROV) or diver. A second suitable configuration is one in which such a support unit is omitted and the cleaning unit is coupled directly with an ROV. A third example configuration is one in which the body encircles the subsea structure being cleaned and the cleaning unit has substantial autonomy. Other suitable configurations may be used by those of skill in the art.

<u>Figures 4a & 4b:</u>

Figure 4a illustrates a top view of a cleaning unit adjusted for cleaning of a tubular having a fairing attached thereto. Cleaning unit 402 includes links 418 attached at their ends with connectors 420. Links 418 and connectors 420 may be substantially similar to links 218 and connectors 220 discussed in reference to Figures 2b, 2c, 2d, 2e and 2f. Bristles 422 may be similar to those previously discussed in reference to Figure 2c and 2d are attached to links 418. Although bristles 422 are illustrated in Figure 4a, it is contemplated that any one or a combination of the cleaning components previously discussed in reference to Figures 2b, 2c, 2d, 2e and 2f (e.g. brushes, water jets or scrapers) may be included in cleaning unit 402 to facilitate cleaning of the underlying structure.

Five links 418 may be adjusted to clean an underlying tubular 404 having fairing 406 attached thereto as illustrated in Figure 4a. Fairing 406 may have any shape and dimension (e.g. tear drop shape or tail fairing) and be mounted to tubular 404 in any manner suitable for suppressing VIV about tubular 404. Representatively, fairing 406 may be substantially similar to, for example, those which are disclosed in U.S. Patent No. 5,984,584; U.S. Patent No. 6,010,278; U.S. Patent No. 6,223,672 and U.S. Patent Publication No. 2006/0021560, which are all herein incorporated by reference in their entirety, or the system may be used to clean other types of fairings as are known in the art.

Cleaning unit 402 further includes arms 410a and 410b to facilitate positioning of adjacent fairings within cleaning unit 402 and cleaning of the fairings and associated tubular. In this aspect, arms 410a and 410b may be attached to links 418 with resilient members 412a, 412b which allow arms to be pushed open around a fairing as illustrated in Figure 4a and close back to a natural, closed position when the fairing is removed as illustrated in Figure 4b. Representatively, resilient members 412a, 412b may be spring hinges or other suitable biasing devices. Arms 410a and 410b may be positioned along links 418 such that when cleaning unit 402 is pushed down tubular 404 (i.e., toward the sea floor) contact with a fairing tail causes arms 410a and 410b to rotate upward (i.e., toward the water surface) and outward (i.e., away from tubular 404). Once the fairing is passed, arms 410a and 410b rotate downward and inward back toward their natural position. Representatively, arms 410a, 410b may be biased toward a center of cleaning unit 402 by connectors 412a and 412b and form approximately 45 degree angles with a bottom surface of links 418 to which they are attached.

In some embodiments, bristles 426 similar to those previously discussed may further be attached to arms 410a and 410b to facilitate cleaning of fairing 406 and tubular 404. Although bristles 426 are illustrated in Figure 4a it is contemplated that other cleaning components (e.g. scrapers, brushes or water jets, or others described in previous figures) may be attached to arms 410a and 410b in addition to or in place of bristles 426 to facilitate cleaning of fairing 406 and tubular 404.

Figure 4b illustrates a top view of the cleaning unit of Figure 4a in a closed position. In this aspect, cleaning unit 402 is shown above fairing 406. Since cleaning unit 402 is not positioned around fairing 406, arms 410a and 410b are returned to their closed positions. Bristles 426 along arms 410a, 410b facilitate cleaning of structures adjacent to fairing 406, for example, tubular 404 and/or collars.

Alternative Embodiments:

In some embodiments, an ROV or diver interface may be provided to allow for some underwater control. In this aspect, the need for an electrical and/or hydraulic umbilical and, if water injection is not needed, the need for an umbilical at all may be eliminated.

It is contemplated that the cleaning device provided herein may be used to clean a variety of different types of VIV suppression devices. Suitable VIV suppression devices may include, but are not limited to, fairings, strakes, shrouds, wake splitters, tail fairings, buoyancy modules, or other devices as are known in the art. Suitable sleeves, suitable collars, and suitable devices for installation 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 5,421,413; 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 installed 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 VIV suppression devices 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 cleaning devices and/or VIV suppression devices 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.

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

The fairings or other VIV suppression devices disclosed herein may be partially manufactured from copper.

<u>Illustrative Embodiments:</u>

In one embodiment, there is disclosed a tool comprising a frame; at least one cleaning device attached to the frame. In some embodiments, the tool comprises a clamshell device comprising at least one set of clamps. In some embodiments, the tool also comprises a connection to a remote location, the remote location comprising a power source. In some embodiments, the frame has a height from 0.5 to 5 meters. In some embodiments, the subsea structures are selected from the group consisting of bare tubulars, vortex-induced vibration reduction devices and drag reduction devices. In some embodiments, the tool also comprises a hydraulic, pnematic, or electric system supported by the frame adapted to open and/or close the frame around the subsea structures. In some embodiments, the cleaning device is selected from brushes, scrapers, water jets, ultrasonic and/or cavition devices. In some embodiments, the frame comprises a plurality of links adapted to surround the subsea structure. In some embodiments, the tool also comprises at least one connector between two adjacent links, the connector adapted to secure the adjacent links in one or more first positions, and allow the links to be disconnected in a second position, wherein the links may be secured in a plurality of positions manually, remotely, or autonomously. In some embodiments, the tool also comprises an ultrasonic cleaning device. In some embodiments, the tool also comprises a propulsion system comprising propellers, rollers, and/or ballast tanks. In some embodiments, the tool also comprises brushes, for example brushes mounted on movable arms. In some embodiments, the tool also comprises scrapers. In some embodiments, the tool also comprises an umbilical connection to a surface vessel. In some embodiments, the tool also comprises a camera and optionally some camera lights. In some embodiments, the tool also comprises non-rotating and rotating portions.

In one embodiment, there is disclosed a method of remotely cleaning a subsea structure, the method comprising positioning a tool adjacent to the subsea structure, wherein the tool comprises at least one cleaning device; moving the tool to position the tool around the subsea structure; closing the tool to a closed configuration to close the tool around the subsea structure, wherein the tool covers from about 10% to about 100% of the diameter of the subsea structure; and activating the cleaning device to clean the subsea structure. In some embodiments, the tool is operated underwater with a remotely operated vehicle. In some embodiments, the tool is closed around the structure above a water level, and is activated to clean the structure below the water level.

In the description above, for the purposes of explanation, numerous specific details have been set forth in order to provide a thorough understanding of the embodiments of the invention. It will be apparent however, to one skilled in the art, that one or more other embodiments may be practiced without some of these specific details. The particular embodiments described are not provided to limit the invention but to illustrate it. The scope of the invention is not to be determined by the specific examples provided above but only by the claims below. In other instances, well-known circuits, structures, devices, and operations have been shown in block diagram form or without detail in order to avoid obscuring the understanding of the description.

It will also be appreciated, by one skilled in the art, that modifications may be made to the embodiments disclosed herein, such as, for example, to the sizes, shapes, configurations, forms, functions, materials, and manner of operation, and assembly and use, of the components of the embodiments. All equivalent relationships to those illustrated in the drawings and described in the specification are encompassed within embodiments of the invention.

It should also be appreciated that reference throughout this specification to "one embodiment", "an embodiment", or “one or more embodiments”, for example, means that a particular feature may be included in the practice of the invention. Similarly, it should be appreciated that in the description various features are sometimes grouped together in a single embodiment, Figure, or description thereof for the purpose of streamlining the disclosure and aiding in the understanding of various inventive aspects. This method of disclosure, however, is not to be interpreted as reflecting an intention that the invention requires more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive aspects may lie in less than all features of a single disclosed embodiment. Thus, the claims following the Detailed Description are hereby expressly incorporated into this Detailed Description, with each claim standing on its own as a separate embodiment of the invention.

TH3592-PCT

# CLAIMS

1. A tool for cleaning subsea structures, the tool comprising:
   (a) a frame;
   (b) at least one cleaning device attached to the frame.

2. The tool of claim 1, wherein the tool comprises a clamshell device comprising at least one set of clamps.

3. The tool of one or more of claims 1-2, further comprising a connection to a remote location, the remote location comprising a power source.

4. The tool of one or more of claims 1-3, wherein the frame has a height from 0.5 to 5 meters.

5. The tool of one or more of claims 1-4, wherein the subsea structures are selected from the group consisting of bare tubulars, vortex-induced vibration reduction devices and drag reduction devices.

6. The tool of one or more of claims 1-5, further comprising a hydraulic, pnematic, or electric system supported by the frame adapted to open and/or close the frame around the subsea structures.

7. The tool of one or more of claims 1-6, wherein the cleaning device is selected from brushes, scrapers, water jets, ultrasonic and/or cavition devices.

8. The tool of one or more of claims 1-7, wherein the frame comprises a plurality of links adapted to surround the subsea structure.

9. The tool of claim 8, further comprising at least one connector between two adjacent links, the connector adapted to secure the adjacent links in one or more first positions,

and allow the links to be disconnected in a second position, wherein the links may be secured in a plurality of positions manually, remotely, or autonomously.

10. A method of remotely cleaning a subsea structure, the method comprising:

(a) positioning a tool adjacent to the subsea structure, wherein the tool comprises at least one cleaning device;

(b) moving the tool to position the tool around the subsea structure;

c) closing the tool to a closed configuration to close the tool around the subsea structure, wherein the tool covers from about 10% to about 100% of the diameter of the subsea structure; and

(d) activating the cleaning device to clean the subsea structure.

11. The method of claim 10, wherein the tool is operated underwater with a remotely operated vehicle.

12. The method of one or more of claims 10-11, wherein the tool is closed around the structure above a water level, and is activated to clean the structure below the water level.

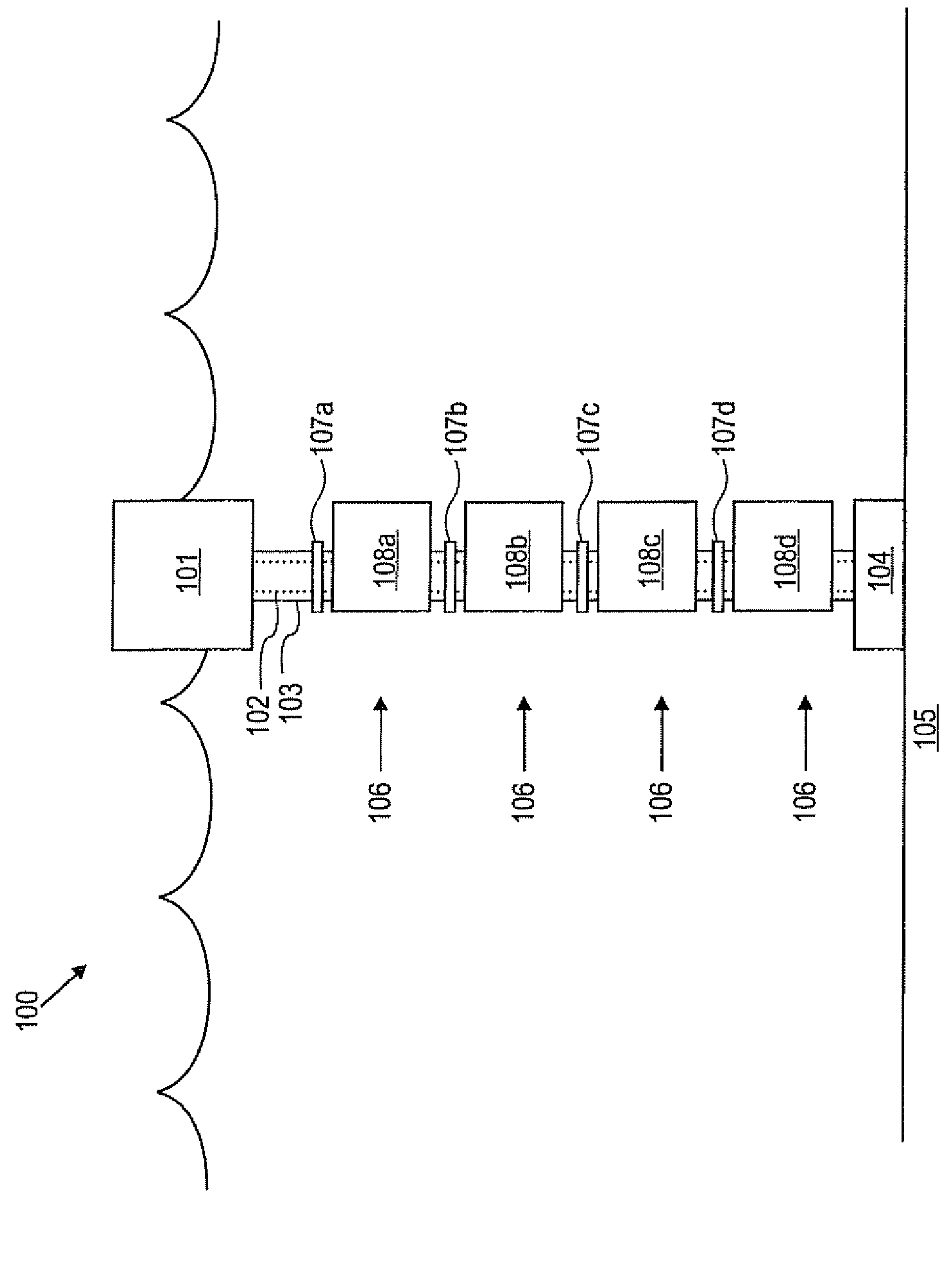
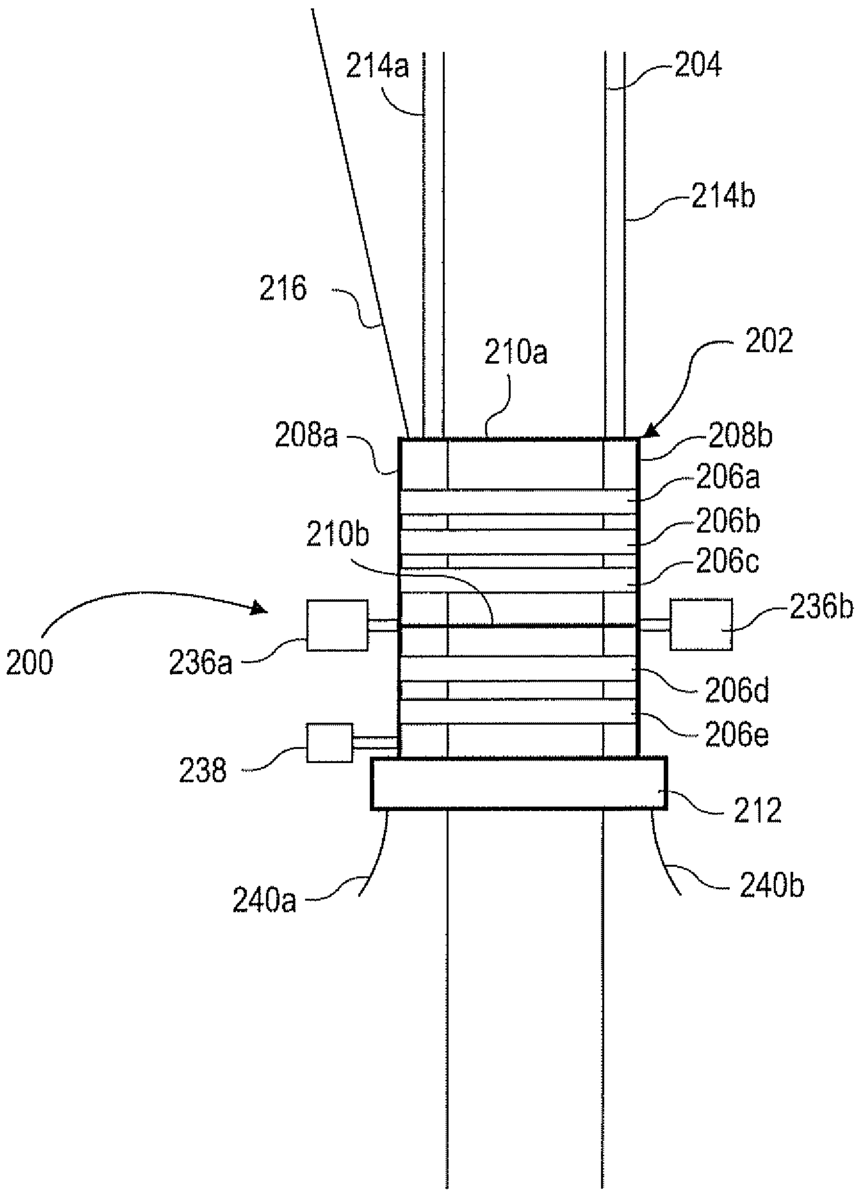

100
101
102
103
106
106
106
106
107a
107b
107c
107d
108a
108b
108c
108d
104
105

FIG. 1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214b
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210a
202
208a
208b
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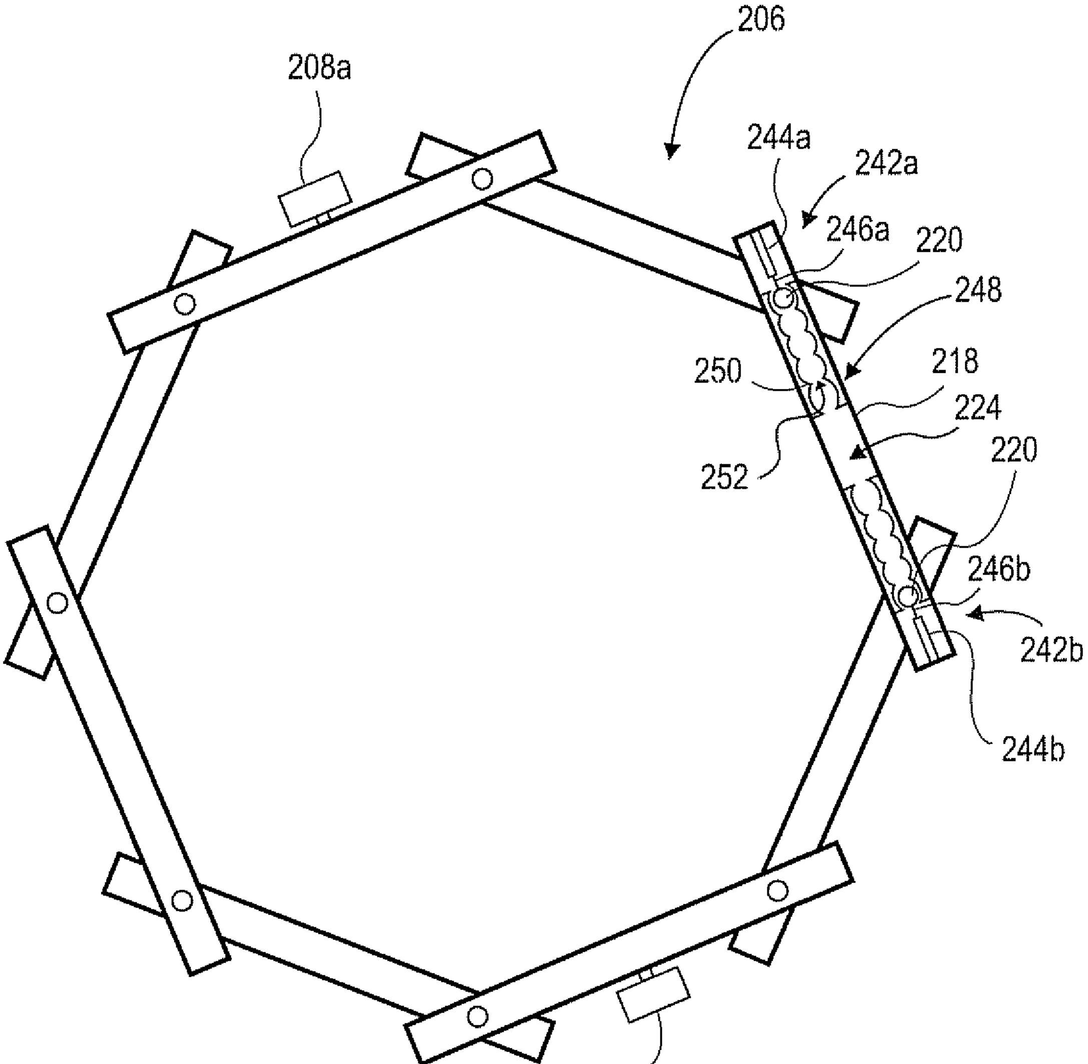
200
236a
236b
206d
206e
238
212
240a
240b

FIG. 2a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248
250
218
224
252
220
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242b
244b
208b

FIG. 2b

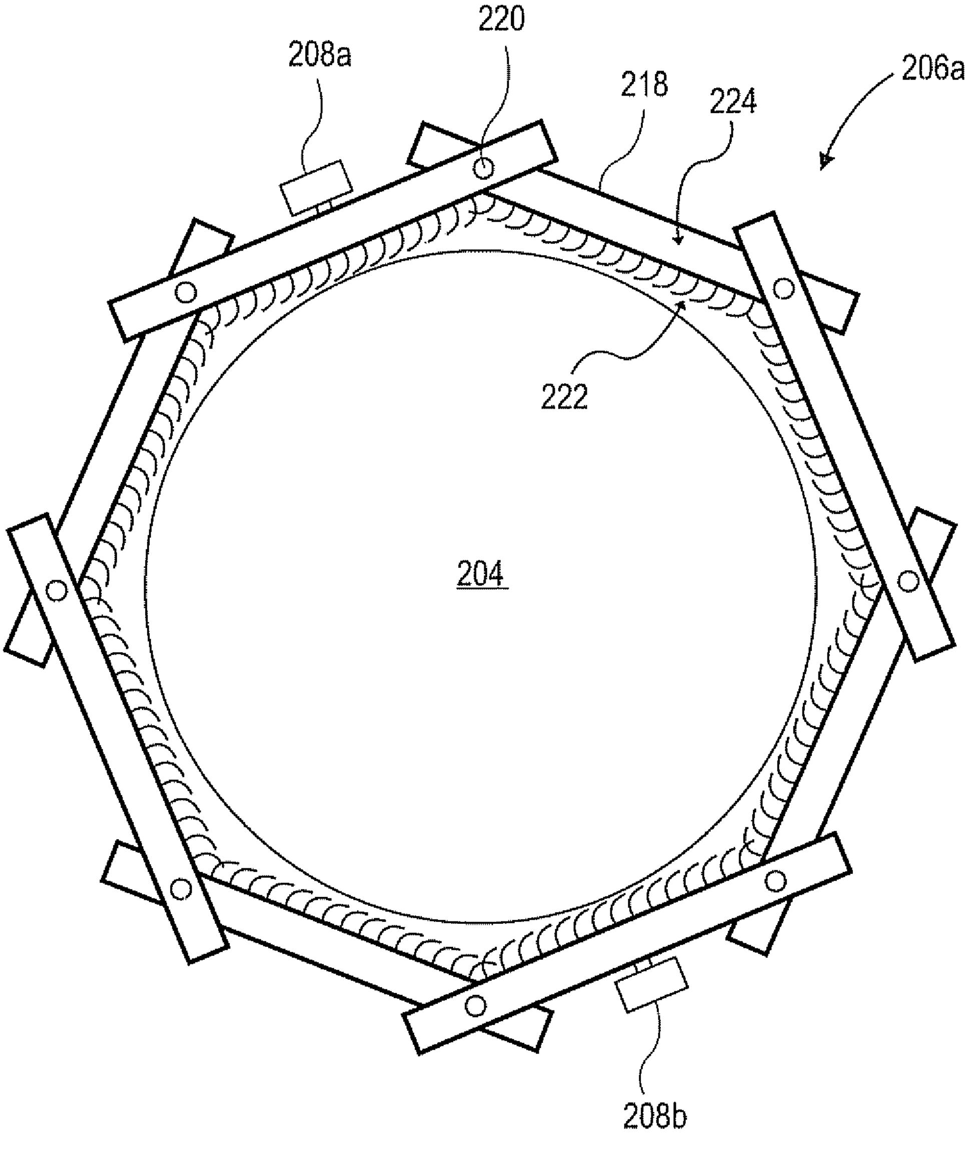


FIG. 2c

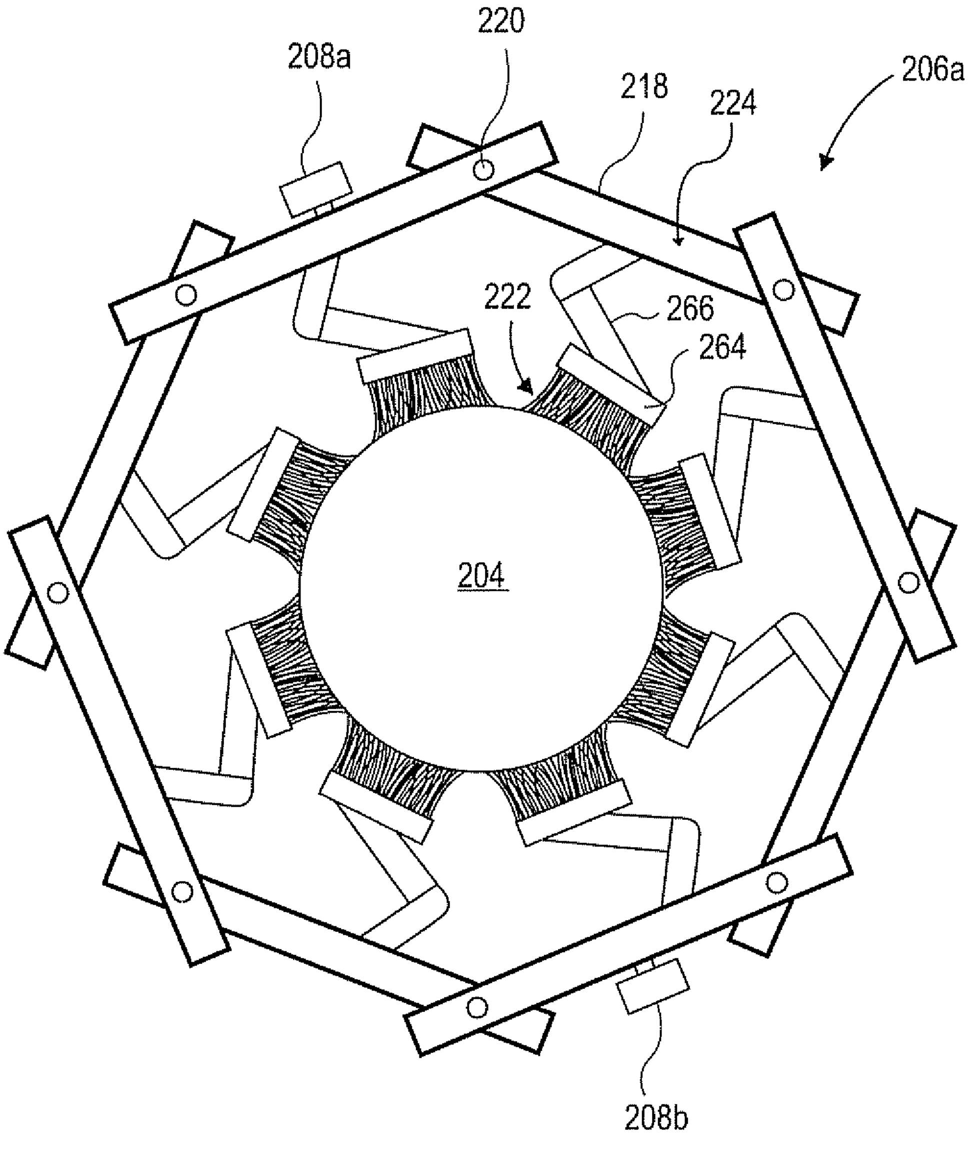


FIG. 2d

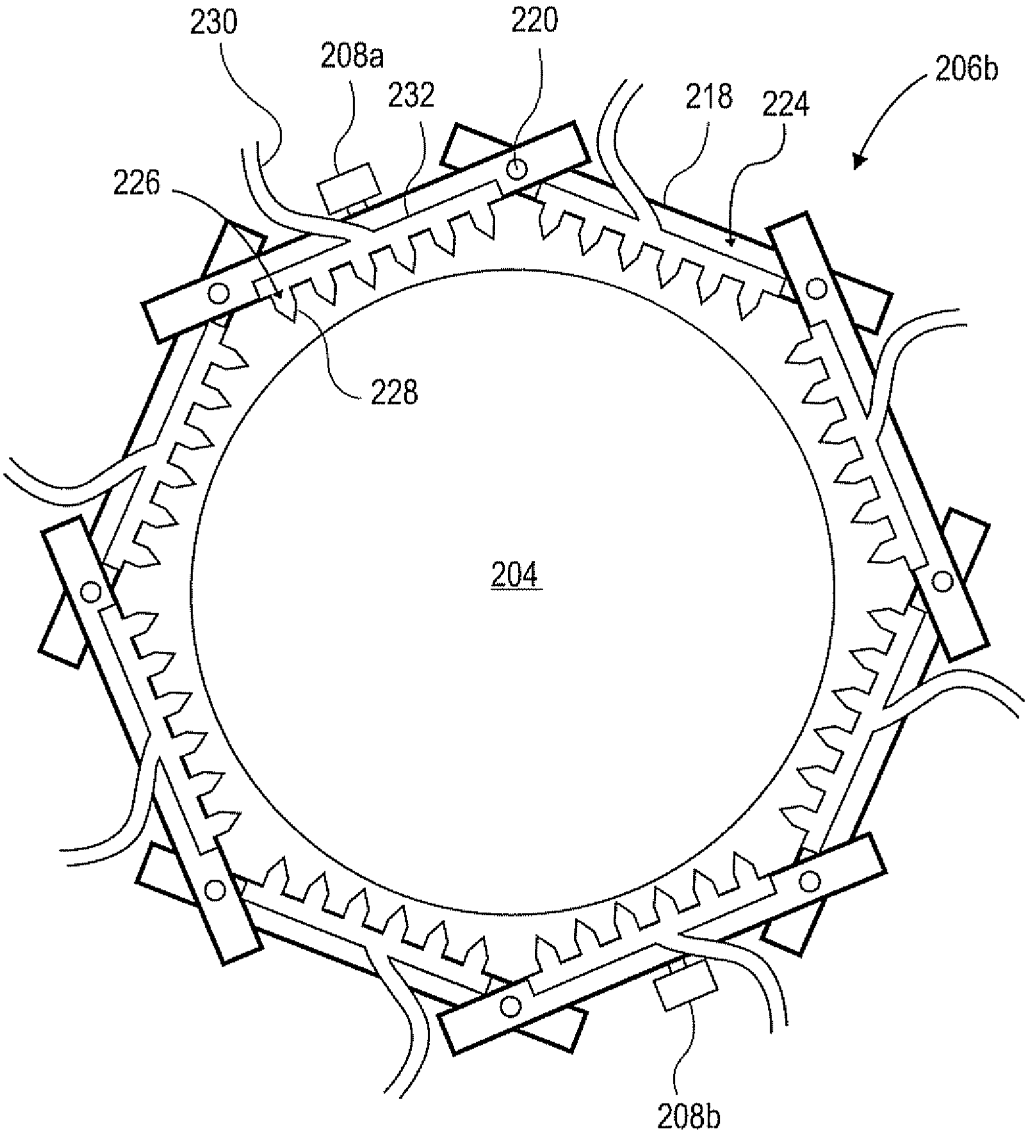


FIG. 2e

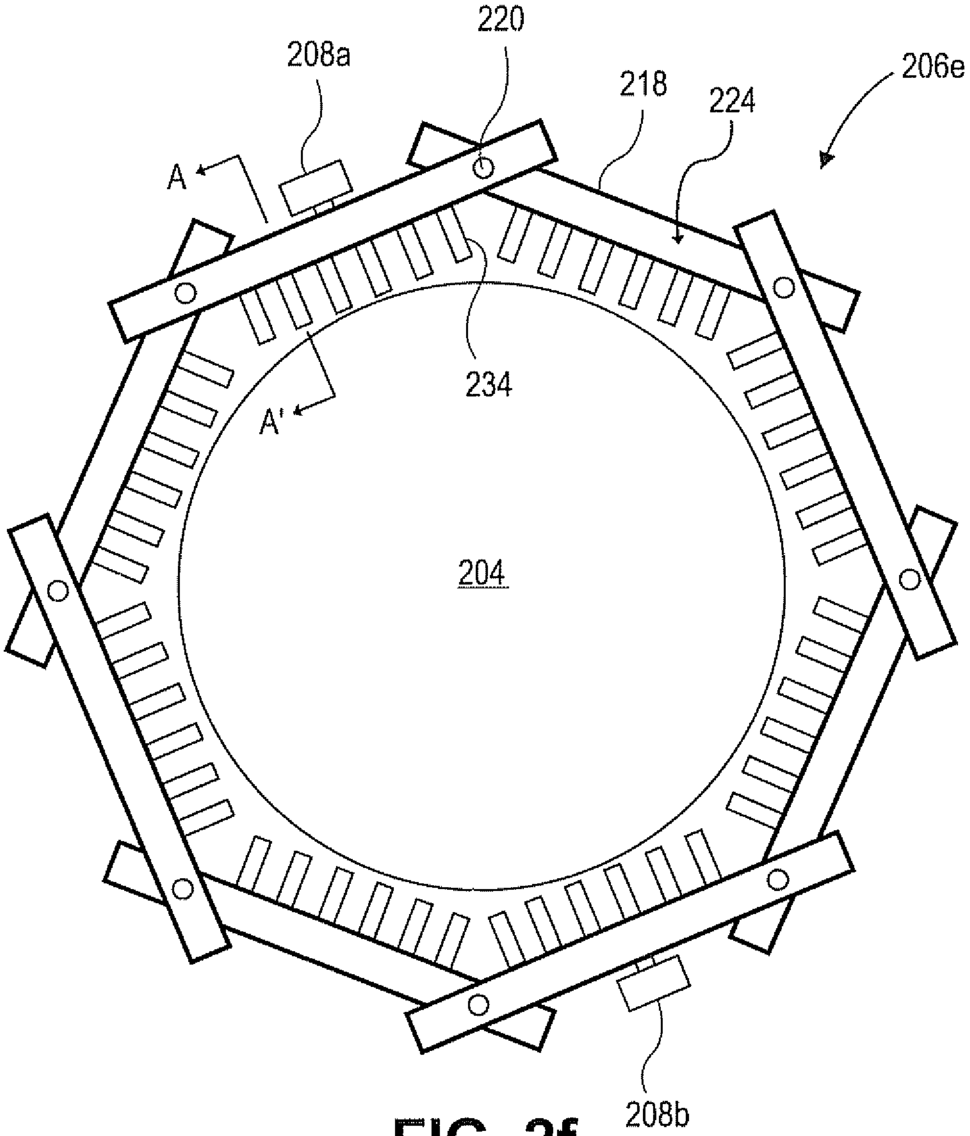


FIG. 2f

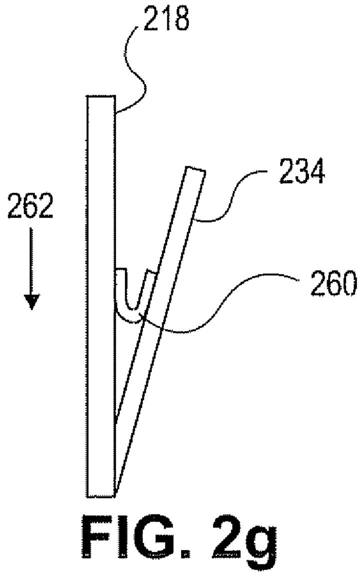


FIG. 2g

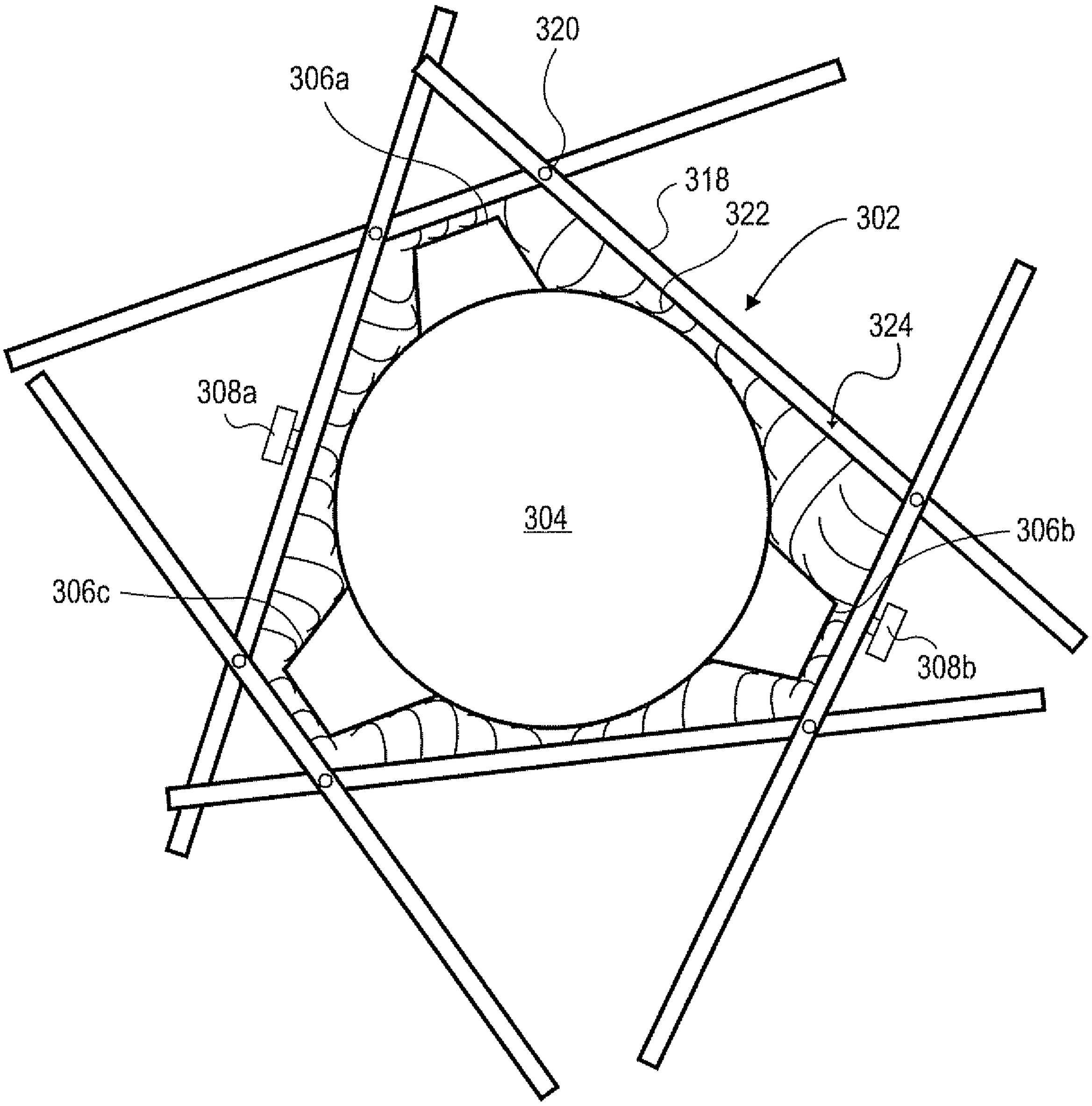


FIG. 3

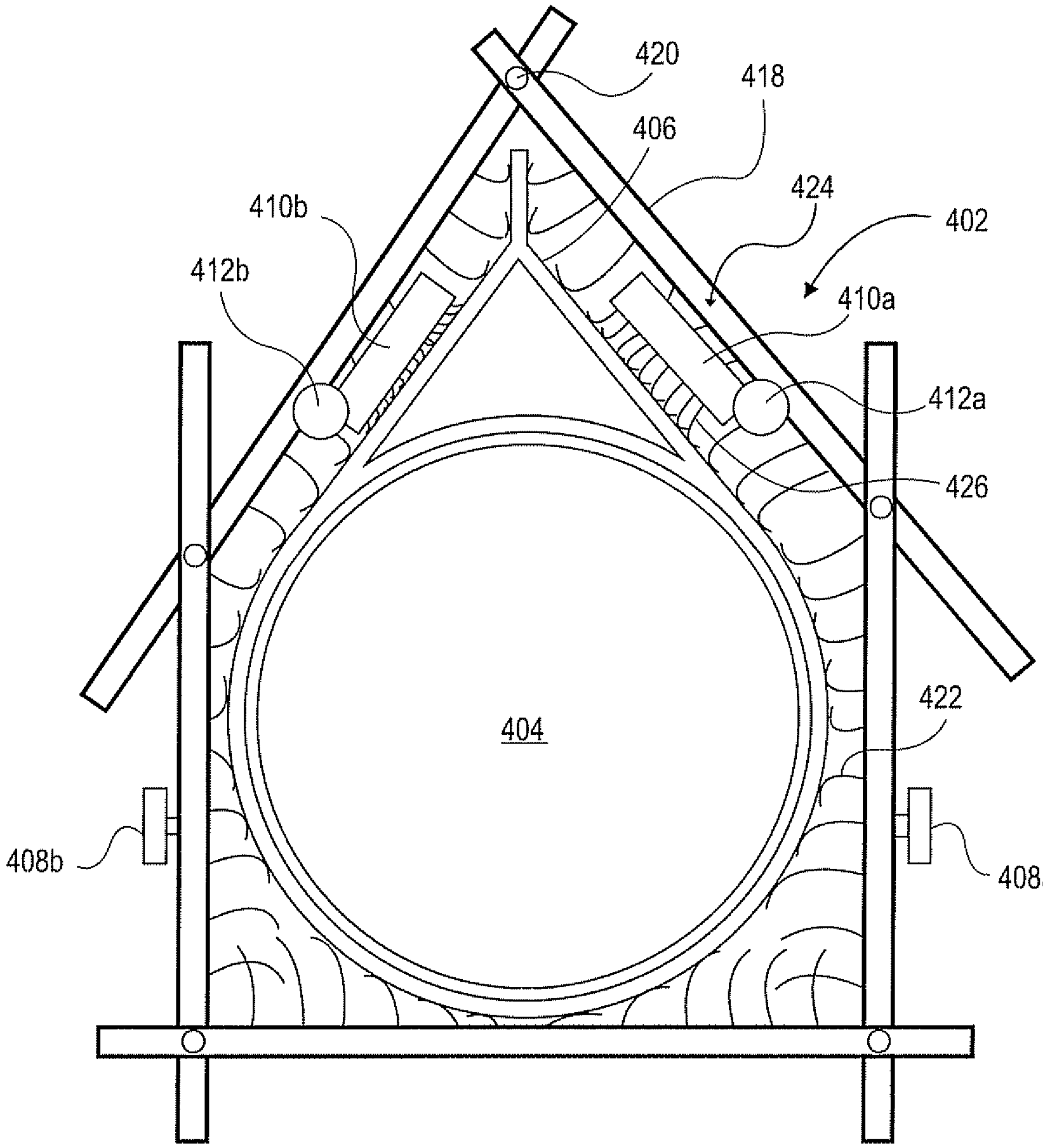


FIG. 4a

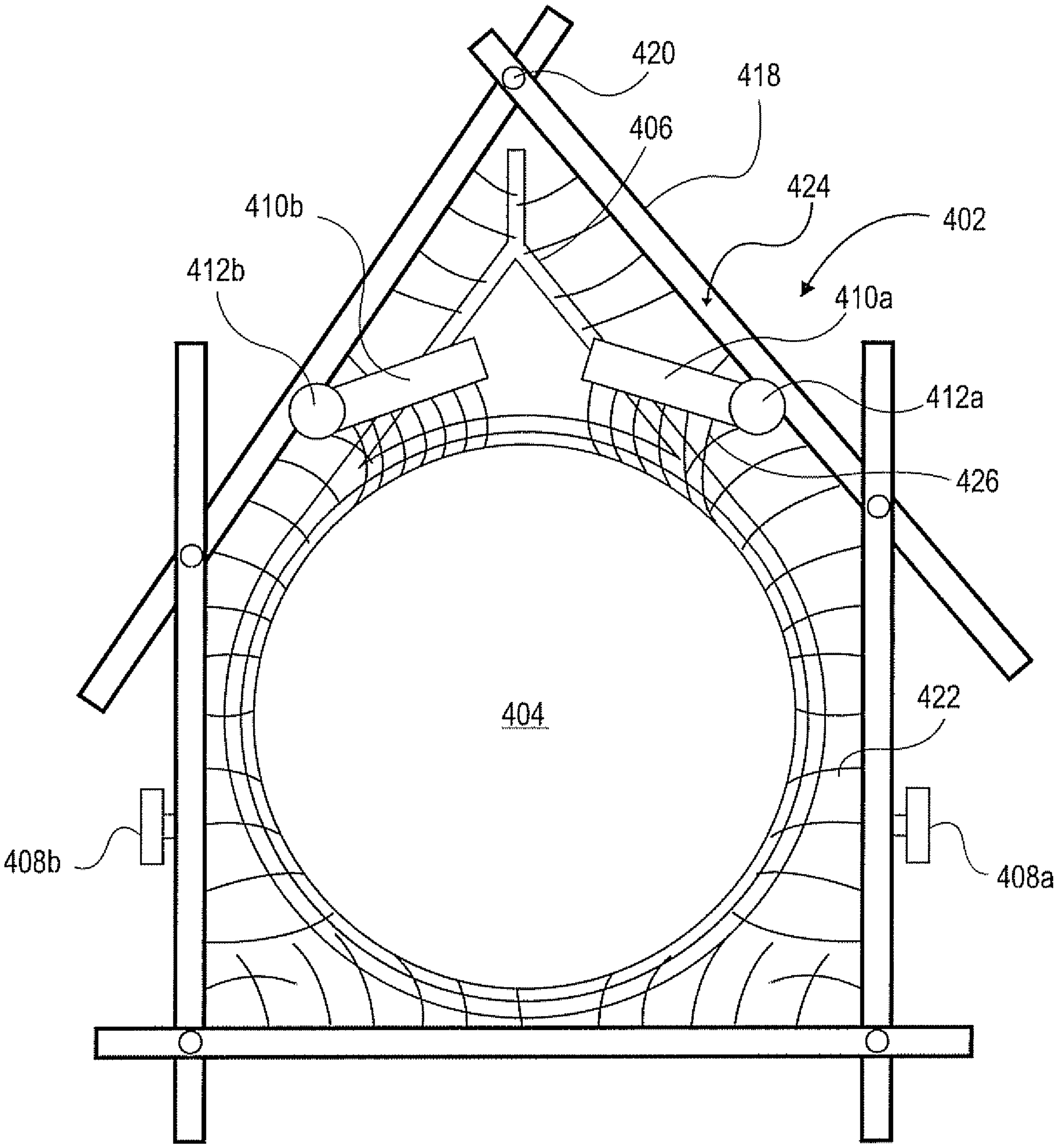


FIG. 4b