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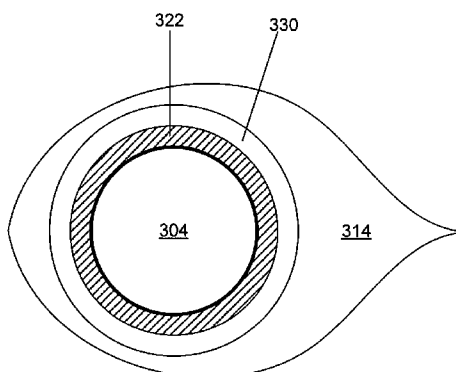
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(54) Title: VORTEX INDUCED VIBRATION SUPPRESSION SYSTEMS AND METHODS

Figure 3b



(57) Abstract: A system comprising a subsea structure defining an interior of the system, the structure subject to a water current; a sleeve exterior to the subsea structure, covering at least a portion of an outside surface of the subsea structure; and a vortex induced vibration suppression device exterior to the sleeve.

WO 2008/100976 A1

VORTEX INDUCED VIBRATION SUPPRESSION SYSTEMS AND METHODS

Field of the Invention

This invention is related to vortex induced vibration suppression systems that can be attached to flexible 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, hoses, umbilicals, and other flexible members.

Umbilicals as used herein are defined to be a non-exclusive example of a marine element subject to VIV. Generally an umbilical system is used for establishing communication between the surface and the bottom of a water body. The principal purpose of the umbilical is to provide a fluid, electrical, and/or optical flow path between a surface vessel and a subsurface structure.

There are generally two kinds of water current induced stresses to which elements of a umbilical 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. 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, an umbilical that is vibrating due to vortex shedding will disrupt the flow of water around it more so than a stationary umbilical. This results in greater energy transfer from the current to the umbilical, 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 5,984,584 discloses a fairing system for protecting multiple, parallel, bundled but separate cylindrical elements deployed in offshore applications. The fairing system deploys a plurality of elongated fairing surface elements foldable about an axis with a connection system joining the elongated edges of the fairing surface elements in a folded manner about the axis. A plurality of thrust bearings are orthogonally connected across the fairing surface elements at each axial end and an axially extending circular rotational surface is defined by the interior of each of the folded fairing surface elements and a transverse edge of the thrust bearings connected thereto. This rotational surface has a diameter which circumscribes the multiple bundled cylindrical elements. A plurality of clamps interconnect the bundled, cylindrical elements and a bearing collar on the axial ends of the clamps is provided to receive the thrust bearings of the axial ends of the fairing elements. U.S. Patent 5,984,584 is herein incorporated by reference in its entirety.

U.S. Patent 7,070,361 discloses an apparatus for suppressing vortex induced vibrations on a marine element of a riser system wherein the riser system

comprises at least one umbilical element. Systems comprising and methods of using said apparatus to suppress vortex induced vibrations. The apparatus, systems, and methods comprise module elements which provide: i) a surface around a marine element for installing VIV suppression devices; and ii) passages for housing the at least one umbilical element. U.S. Patent 7,070,361 is herein incorporated by reference in its entirety.

Referring now to Figure 1, surface structure 102 is in body of water 100. Surface structure 102 is connected to subsurface structure 103 at seabed 108 by connector member 104, such as an umbilical, cable, or tendon. Current 110 encounters connector member 104. To protect connector member 104 from vibration caused by current 110, fairings 114 have been installed. One or more collars (not shown) may be installed between adjacent fairings.

When VIV suppression devices are installed on umbilicals or other flexible structures, there is a danger that the structure will be damaged during the installation procedure. Each VIV suppression device installation around a structure may damage the structure, for example, if the ROV or other installation tool cuts or crimps the structure, runs into or dislodges the structure, and other damage as can be imagined by a person of skill in the art.

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 umbilical systems and other flexible elements and for providing protection to the flexible elements.

There is a need for systems and methods of installing VIV suppression devices to flexible elements without damaging the flexible elements.

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

Summary of the Invention

In one aspect, the invention provides a system comprising a subsea structure defining an interior of the system, the structure subject to a water current; a sleeve exterior to the subsea structure, covering at least a portion of an outside

surface of the subsea structure; and a vortex induced vibration suppression device exterior to the sleeve.

In another aspect, the invention provides a method comprising installing a subsea structure in a body of water, wherein the subsea structure is subject to one or more water currents; installing at least one sleeve exterior to the subsea structure, covering at least a portion of an outside surface of the subsea structure; and installing at least one vortex induced vibration suppression device exterior to the sleeve.

Advantages of the invention may include one or more of the following:
improved apparatus and methods for suppressing VIV;
apparatus and methods for suppressing VIV that do not suffer from the disadvantages of the prior art;

apparatus and methods for providing VIV suppression to an umbilical or other flexible elements and for providing protection to the flexible elements;

systems and methods of installing VIV suppression devices to flexible elements without damaging the flexible elements; and/or

systems and methods of installing VIV suppression devices to subsea structures without damaging the structure.

Brief Description of the Figures

Figure 1 illustrates an oil and/or gas production system.

Figure 2a illustrates an oil and/or gas production system.

Figure 2b illustrates an oil and/or gas production system.

Figure 3a illustrates an oil and/or gas production system.

Figure 3b illustrates a cross-sectional view of the oil and/or gas production system of Figure 3a.

Figure 4 illustrates an oil and/or gas production system.

Figure 5a illustrates an oil and/or gas production system.

Figure 5b illustrates an oil and/or gas production system.

Detailed Description

Referring now to Figure 2a, system 200 is illustrated. System 200 includes surface structure 202 near the surface of the water, which is attached to connector member 204. Connector member 204 is also connected to subsurface structure 203 near seafloor 208. Exterior to connector member 204 near seafloor 208,

collar 220 has been installed. Exterior to connector member 204, sleeves 222 have been installed, which rest on collar 220.

Referring now to Figure 2b, fairings 214 have been installed exterior to sleeves 222. Sleeves 222 allow fairings 214 to be installed with less risk of damaging connector member 204. Fairings 214 act to reduce drag and/or vortex induced vibration acting on connector member 204 due to current 210. Fairings 214 and/or sleeves 222 may be heavier than water so that they sink to rest on collar 220.

Referring now to Figure 3a, system 300 is illustrated. System 300 includes surface structure 302 near the surface of the water, which is attached to connector member 304. Connector member 304 is also connected to subsurface structure 303 near seafloor 308. Exterior to connector member 304 near surface structure 302, collar 320 has been installed. Exterior to connector member 304, sleeves 322 have been installed, which rest on collar 320. Fairings 314 have been installed exterior to sleeves 322. Sleeves 322 allow fairings 314 to be installed with less risk of damaging connector member 304. Fairings 314 act to reduce drag and/or vortex induced vibration acting on connector member 304 due to current 310. Fairings 314 and/or sleeves 322 may be lighter than water so that they float to rest on collar 320.

Referring now to Figure 3b, a cross-sectional view of system 300 is shown. Connector member 304 defines an interior of the system. Sleeve 322 has been installed exterior to connector member 304. Fairing 314 has been installed exterior to sleeve 322. Space 330 is defined between the exterior of sleeve 322 and the interior of fairing 314, which allows fairing 314 to weathervane with varying current directions.

Referring now to Figure 4, system 400 is illustrated. System 400 includes surface structure 402 near the surface of the water, which is attached to connector member 404. Connector member 404 is also connected to subsurface structure 403 near seafloor 408. Exterior to connector member 404 near subsurface structure 403, collar 420 has been installed. Exterior to connector member 404, sleeves 422 and sleeves 424 have been installed, which rest on collar 420. Fairings 414 have been installed exterior to sleeves 422 and sleeves 424. Sleeves 424 may be installed between every about 1 to about 10 sleeves 422.

Sleeves 424 have flange 426. Flange 426 has a larger diameter than an interior diameter of fairing 414, which acts to provide a bearing surface that the fairing 414 above and/or the fairing below can rotate on. Flange 426 may be copper to retard marine growth.

Sleeves 422 and sleeves 424 allow fairings 414 to be installed with less risk of damaging connector member 404. Fairings 414 act to reduce drag and/or vortex induced vibration acting on connector member 404 due to current 410. Fairings 414, sleeves 424, and/or sleeves 422 may be lighter than water so that they float to rest on collar 420.

Referring now to Figure 5a, system 500 is illustrated. System 500 includes surface structure 502 near the surface of the water, which is attached to connector member 504. Connector member 504 is also connected to subsurface structure 503 near seafloor 508. Exterior to connector member 504 near surface structure 502, collar 520 has been installed. Exterior to connector member 504, sleeve 522 has been installed, near subsurface structure 503. Fairings 514 have been installed exterior to sleeve 522 with tool 530 having attachment mechanism 532, for example arms, to grip fairings 514. Sleeve 522 allows fairings 514 to be installed with less risk of damaging connector member 504. Fairings 514 act to reduce drag and/or vortex induced vibration acting on connector member 504 due to current 510. Fairings 514 may be lighter than water so that they float to rest on collar 520.

Referring now to Figure 5b, system 500 is illustrated. System 500 includes surface structure 502 near the surface of the water, which is attached to connector member 504. Connector member 504 is also connected to subsurface structure 503 near seafloor 508. Exterior to connector member 504 near subsurface structure 503, collar 520 has been installed. Exterior to connector member 504, sleeve 522 has been installed, near surface structure 502. Fairings 514 have been installed exterior to sleeve 522 with tool 530 having attachment mechanism 532, for example arms, to grip fairings 514. Sleeve 522 allows fairings 514 to be installed with less risk of damaging connector member 504. Fairings 514 act to reduce drag and/or vortex induced vibration acting on connector member 504 due to current 510. Fairings 514 may be heavier than water so that they float to rest on collar 520.

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 sleeves, 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 sleeves, collars, and other devices to install exterior to sleeves, 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 collars and/or sleeves may be installed on the connector member before or after the connector member is placed in a body of water.

The sleeves may be made of a high strength material having a Young's Modulus (or modulus of elasticity) of at least about 2 GPa, for example at least about 5 GPa, for example at least about 10 GPa, for example at least about 25 GPa, for example at least about 50 GPa, for example at least about 75 GPa, for example at least about 100 GPa, for example at least about 200 GPa.

The sleeves may be round, or have some ovality or a fairing shape.

The sleeves, collars, fairings and/or other devices exterior to the sleeves 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.

Collars may be placed between adjacent fairings, or between every 2 to 10 fairings. The collar may be a copper ring.

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.

A biodegradable spacer may be placed between adjacent fairings to keep them from binding and allow them to weathervane after the spacer has degraded.

The connector member 404 may be made of a low strength material and/or have a low strength material as a covering, for example having a Young's Modulus (or modulus of elasticity) of less than about 2 GPa, for example less than about 1 GPa, for example less than about 0.5 GPa, for example less than about 0.25 GPa, for example less than about 0.1 GPa.

In one embodiment, there is disclosed a system comprising a subsea structure defining an interior of the system, the structure subject to a water current; a sleeve exterior to the subsea structure, covering at least a portion of an outside surface of the subsea structure; and a vortex induced vibration suppression device exterior to the sleeve. In some embodiments, the subsea structure is selected from an umbilical, a riser, and a tendon. In some embodiments, the sleeve comprises an exterior surface having a Young's modulus of at least 2 GPa. In some embodiments, the vortex induced vibration suppression device comprises a fairing or a helical strake. In some embodiments, the subsea structure comprises an exterior surface having a Young's modulus less than 2 GPa. In some embodiments, the sleeve is buoyant in water, the system further comprising a collar connected to the subsea structure above the sleeve, the collar adapted to

retain the sleeve in an axial location along the subsea structure. In some embodiments, the sleeve is negatively buoyant in water, the system further comprising a collar connected to the subsea structure below the sleeve, the collar adapted to retain the sleeve in an axial location along the subsea structure. In some embodiments, the sleeve comprises one or more ledges extending exterior to the sleeve, for example circumferential ledges. In some embodiments, the vortex induced vibration suppression device comprises one or more shoulders adapted to interface with the one or more ledges. In some embodiments, the system also includes a plurality of sleeves. In some embodiments, the system also includes a plurality of vortex induced vibration suppression devices exterior to the plurality of sleeves. In some embodiments, the system also includes a collar between two adjacent vortex induced vibration suppression devices.

In one embodiment, there is disclosed a method comprising installing a subsea structure in a body of water, wherein the subsea structure is subject to one or more water currents; installing at least one sleeve exterior to the subsea structure, covering at least a portion of an outside surface of the subsea structure; and installing at least one vortex induced vibration suppression device exterior to the sleeve. In some embodiments, the method also includes installing at least one collar exterior to the subsea structure, the collar adapted to retain the sleeve in an axial location along the subsea structure. In some embodiments, the sleeve comprises an exterior surface having a Young's modulus of at least 2 GPa. In some embodiments, the subsea structure comprises an exterior surface having a Young's modulus less than 2 GPa. In some embodiments, the sleeves are installed on the subsea structure before the subsea structure is installed in the body of water. In some embodiments, the vortex induced vibration suppression device are installed on the subsea structure after the subsea structure is installed in the body of water.

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

C L A I M S

1. A system, comprising:
 - a subsea structure defining an interior of the system, the structure subject to a water current;
 - a sleeve exterior to the subsea structure, covering at least a portion of an outside surface of the subsea structure; and
 - a vortex induced vibration suppression device exterior to the sleeve.
2. The system of claim 1, wherein the subsea structure is selected from an umbilical, a riser, and a tendon.
3. The system of one or more of claims 1-2, wherein the sleeve comprises an exterior surface having a Young's modulus of at least 2 GPa.
4. The system of one or more of claims 1-3, wherein the vortex induced vibration suppression device comprises a fairing or a helical strake.
5. The system of one or more of claims 1-4, wherein the subsea structure comprises an exterior surface having a Young's modulus less than 2 GPa.
6. The system of one or more of claims 1-5, wherein the sleeve is buoyant in water, the system further comprising a collar connected to the subsea structure above the sleeve, the collar adapted to retain the sleeve in an axial location along the subsea structure.
7. The system of one or more of claims 1-5, wherein the sleeve is negatively buoyant in water, the system further comprising a collar connected to the subsea structure below the sleeve, the collar adapted to retain the sleeve in an axial location along the subsea structure.

8. The system of one or more of claims 1-7, wherein the sleeve comprises one or more ledges extending exterior to the sleeve, for example circumferential ledges.
9. The system of claim 8, wherein the vortex induced vibration suppression device comprises one or more shoulders adapted to interface with the one or more ledges.
10. The system of one or more of claims 1-9, further comprising a plurality of sleeves.
11. The system of claim 10, further comprising a plurality of vortex induced vibration suppression devices exterior to the plurality of sleeves.
12. The system of claim 11, further comprising a collar between two adjacent vortex induced vibration suppression devices.
13. A method, comprising:
 - installing a subsea structure in a body of water, wherein the subsea structure is subject to one or more water currents;
 - installing at least one sleeve exterior to the subsea structure, covering at least a portion of an outside surface of the subsea structure; and
 - installing at least one vortex induced vibration suppression device exterior to the sleeve.
14. The method of claim 13, further comprising:
 - installing at least one collar exterior to the subsea structure, the collar adapted to retain the fairing and/or the sleeve in an axial location along the subsea structure.
15. The method of one or more of claims 13-14, wherein the sleeve comprises an exterior surface having a Young's modulus of at least 2 GPa.

16. The method of one or more of claims 13-15, wherein the subsea structure comprises an exterior surface having a Young's modulus less than 2 GPa.
17. The method of one or more of claims 13-16, wherein the sleeve is installed on the subsea structure before the subsea structure is installed in the body of water.
18. The method of one or more of claims 13-17, wherein the vortex induced vibration suppression device is installed on the subsea structure after the subsea structure is installed in the body of water.

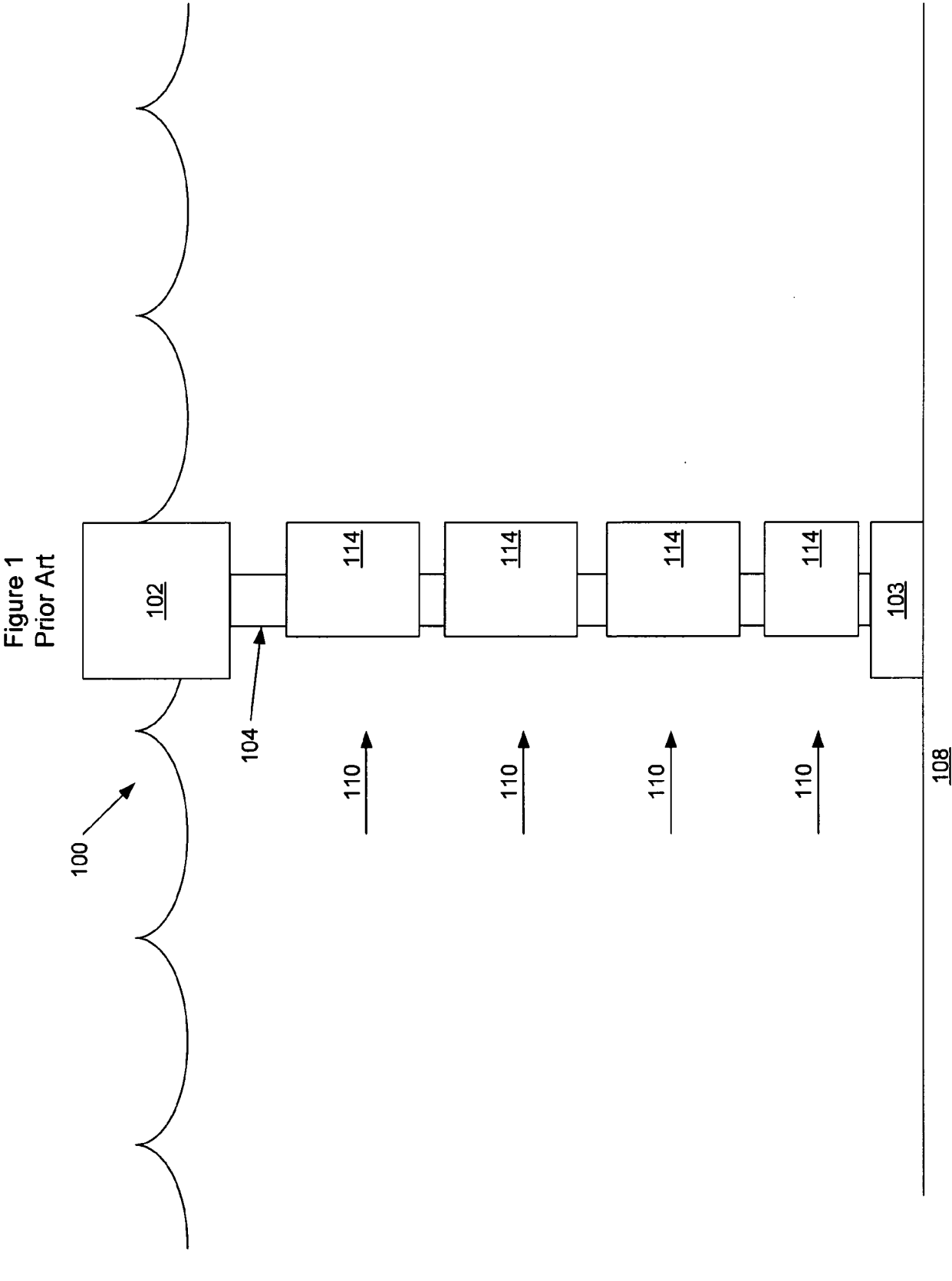


Figure 2a

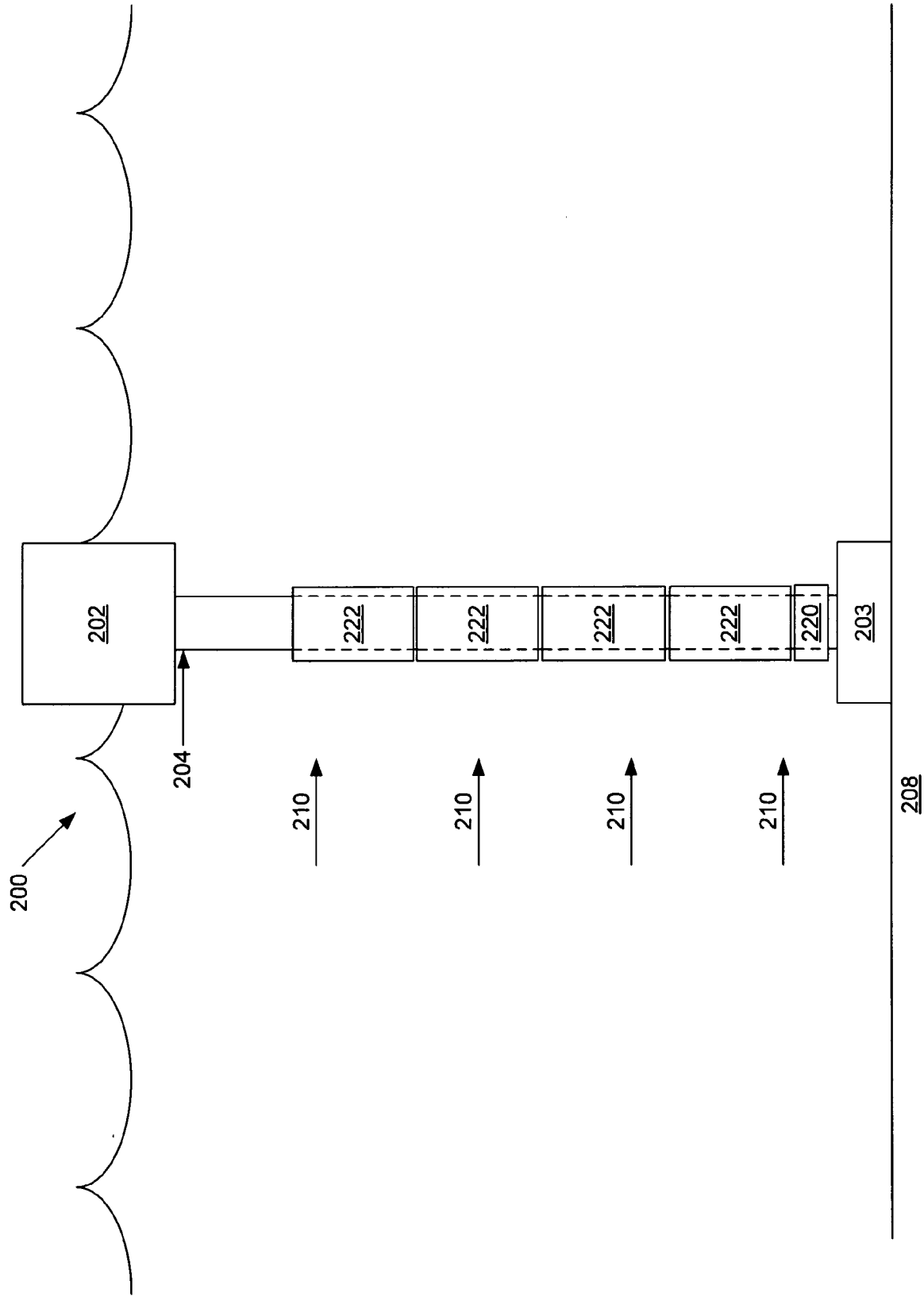


Figure 2b

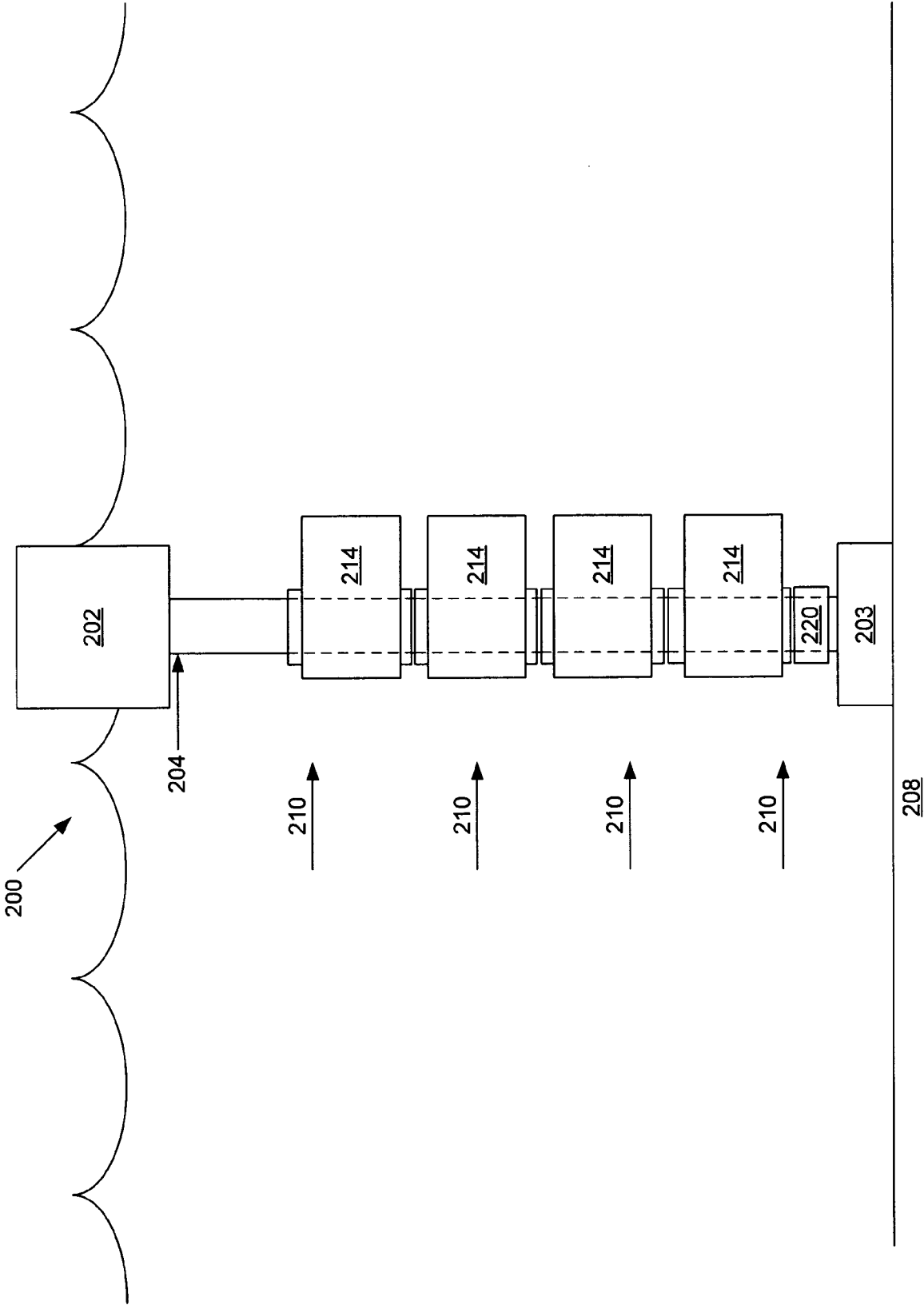
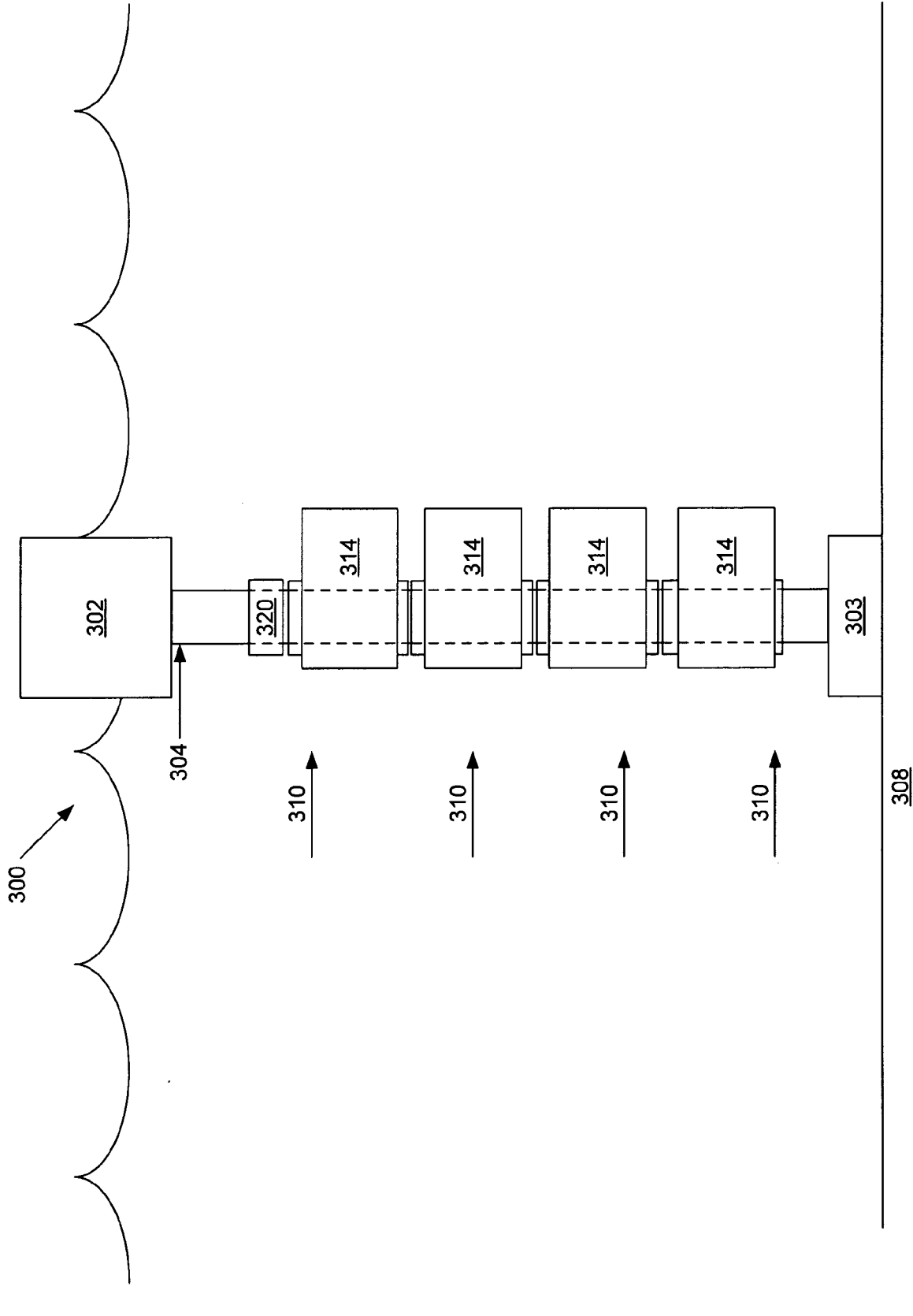


Figure 3a



TH3166 - WEH

Figure 3b

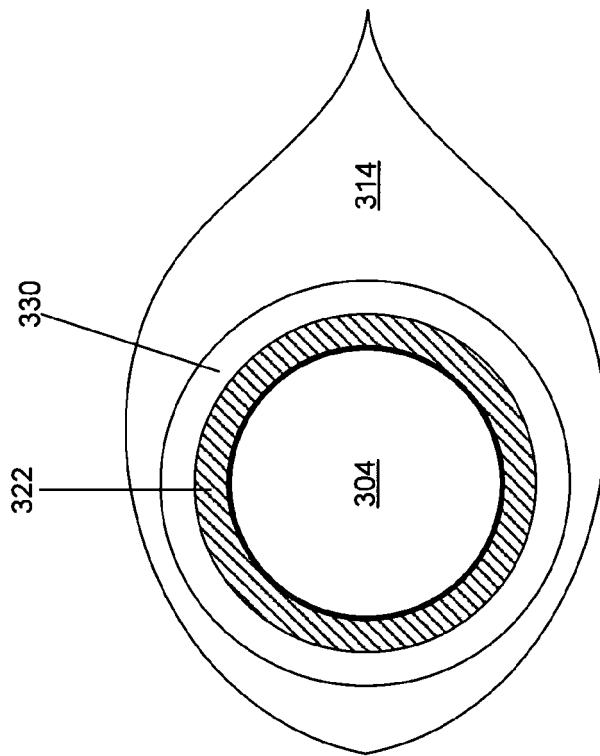


Figure 4

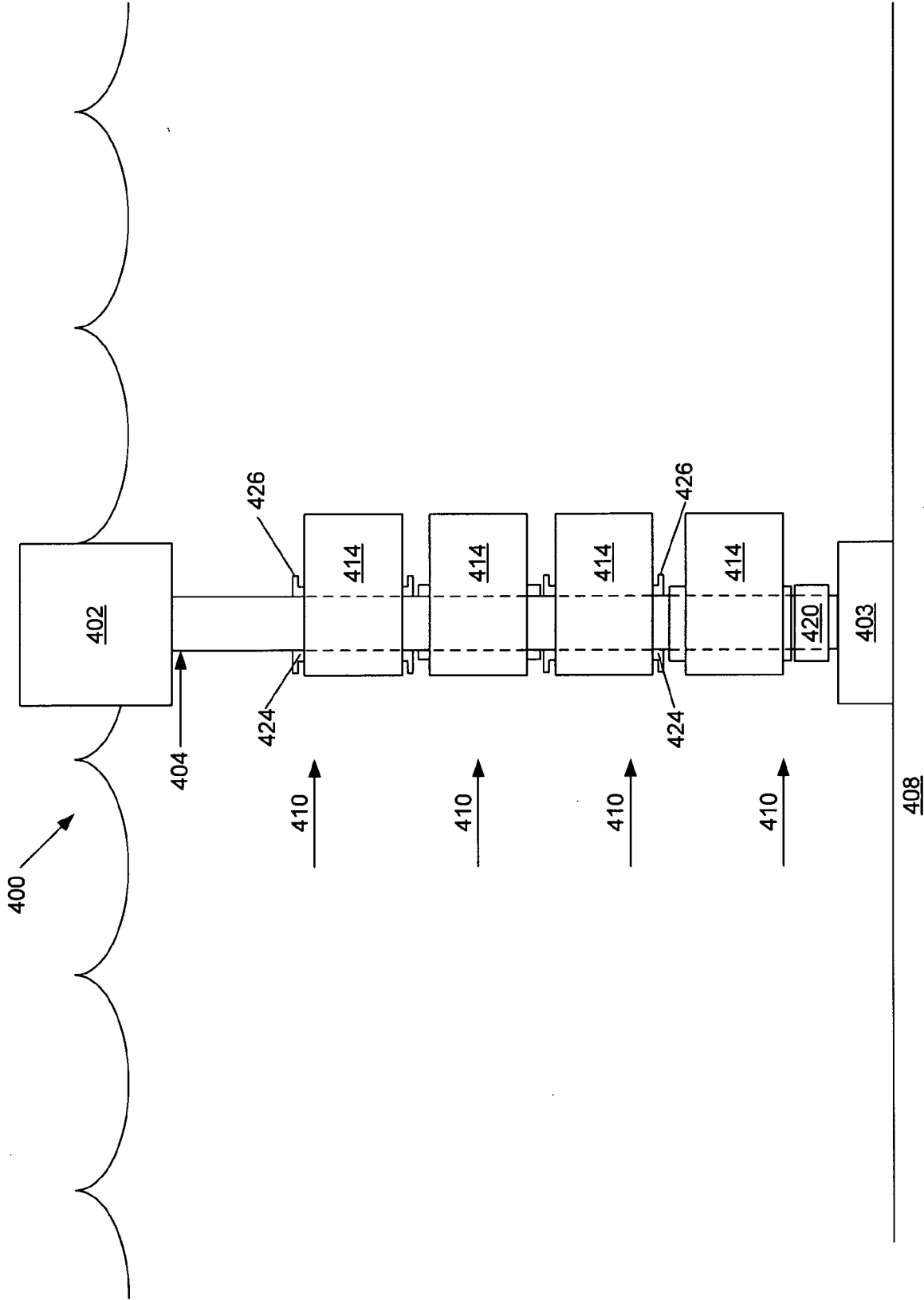


Figure 5a

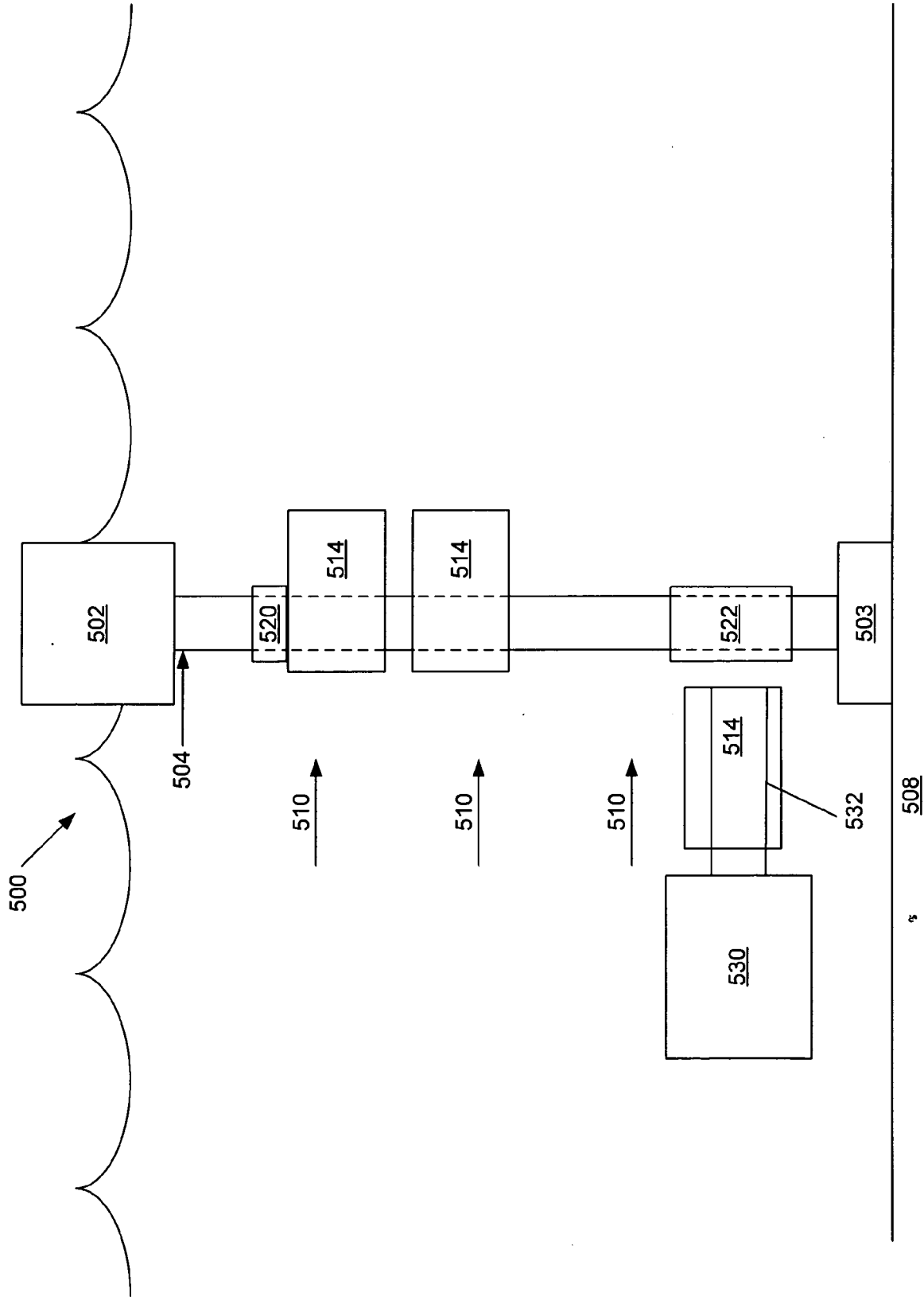
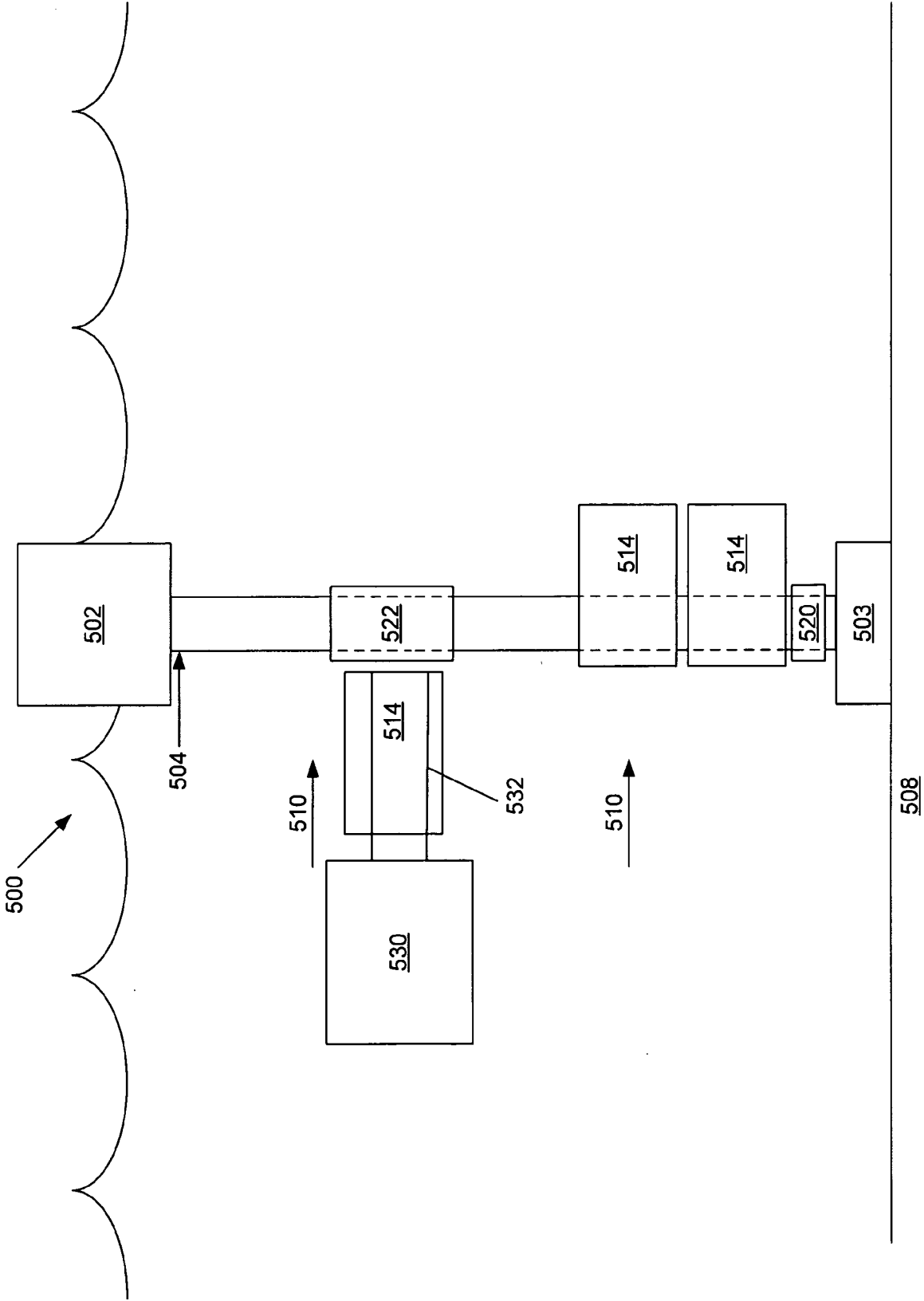


Figure 5b



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 08/53784

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - E02D 5/62, E02D 15/02 (2008.04)

USPC - 405/224.3

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 5/62, E02D 15/02 (2008.04)

USPC: 405/224.3

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC: 405/211, 212, 216, 224, 224.2; 114/243; 166/367, 356

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

PubWEST (USPT, PGPB, EPAB, JPAB); Google/Patents; Google/Scholar

Search Terms: underwater, undersea, submarine, subsea, marine, vibration, fatigue, control, suppression, minimize, prevention, lessen, reduce, decrease, VIV, sleeve, sheath, vortex, fairing, streamline, aerodynamic, riser, umbilical, tendon, elastic, modulus

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2007/0003372 A1 (ALLEN et al.) 04 January 2007 (04.01.2007), Figs. 1 and 2; para [0004], [0005], [0034], [0037], [0052], and [0053]	1, 2, 13, 14 ----- 3, 15
Y	US 6,347,911 B1 (BLAIR et al.) 19 February 2002 (19.02.2002), col 3, lns 10-15; col 5, lns 24-29	3, 15

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

* Special categories of cited documents:

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

02 July 2008 (02.07.2008)

Date of mailing of the international search report

14 JUL 2008

Name and mailing address of the ISA/US

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

Facsimile No. 571-273-3201

Authorized officer:

Lee W. Young

PCT Helpdesk: 571-272-4300
PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 08/53784

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.: 4-12 and 16-18
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.