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(54) Title: RISER ASSEMBLY AND METHOD

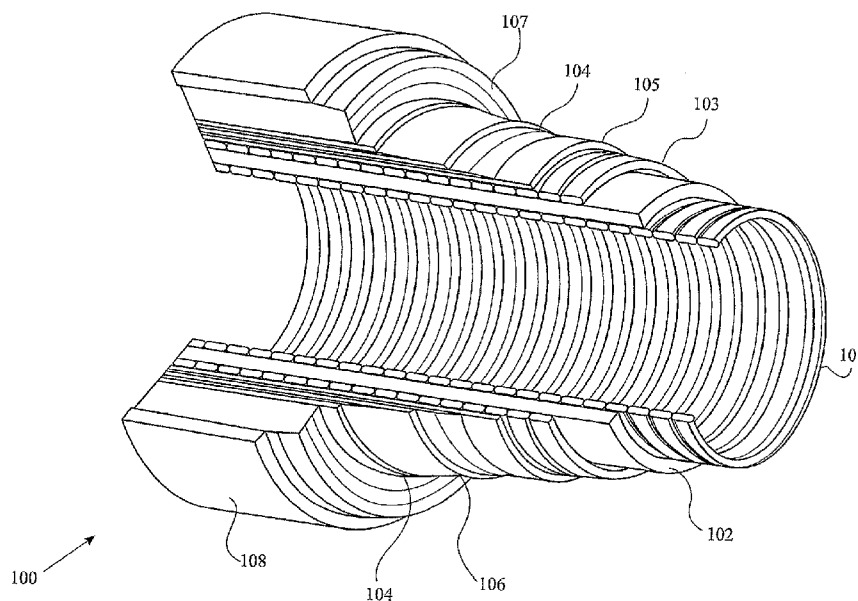


Fig. 1

(57) Abstract: A riser assembly and method of producing a riser assembly are disclosed. The riser assembly includes a riser having a plurality of buoyancy elements provided at predetermined intervals along the length of the riser for supporting the riser, and at least one further buoyancy element arranged to support the riser in a configuration for accommodating tension changes in the riser due to vessel movement.





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RISER ASSEMBLY AND METHOD

FIELD

5 The present invention relates to a method and apparatus for providing a riser assembly. In particular, but not exclusively, the present invention relates to a riser assembly suitable for use in the oil and gas industry, especially in deep and ultra-deep water applications, providing improved performance against problems associated with deeper water depth and excessive vessel motion.

10

BACKGROUND

Traditionally flexible pipe is utilised to transport production fluids, such as oil and/or gas and/or water, from one location to another. Flexible pipe is particularly useful in connecting a sub-sea location (which may be deep underwater) to a sea level
15 location. Flexible pipe is generally formed as an assembly of a flexible pipe body and one or more end fittings. The pipe body is typically formed as a combination of layered materials that form a pressure-containing conduit. The pipe structure allows for deflections, to some degree, without causing bending stresses that impair the pipe's functionality over its lifetime. The pipe body is generally built up as a combined
20 structure including metallic and polymer layers.

Unbonded flexible pipe has been used for deep water (less than 3,300 feet (1,005.84 metres)) and ultra-deep water (greater than 3,300 feet) developments. It is the increasing demand for oil which is causing exploration to occur at greater and greater depths where environmental factors are more extreme. In many known flexible pipe
25 designs the pipe body includes one or more tensile armour layers. The primary loading on such a layer is tension. In high pressure applications, such as in deep and ultra-deep water environments, the tensile armour layer experiences high tension loads from a combination of the internal pressure end cap load and the self-supported weight of the

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flexible pipe. As a result of deeper water depth, the higher tension loads and higher tension load variation can cause fatigue damage and immature fatigue failure in the flexible pipe since such conditions are experienced over prolonged periods of time.

One technique which has been attempted in the past to in some way alleviate the
5 above-mentioned problems is the addition of buoyancy aids at predetermined locations along the length of a vertical or catenary riser, which is suspended from a floating facility and extending to the seabed. WO 2007/125276 discloses such a Stepped riser. The buoyancy aids provide an upwards lift to counteract the weight of the riser, effectively taking a portion of the weight of the riser, at various points along its length.

10 Figure 2 illustrates a known riser assembly 200 suitable for transporting production fluid such as oil and/or gas and/or water from a sub-sea location 201 to a floating facility 202. For example, in Figure 2 the sub-sea location 201 is a sub-sea flow line 203. The flexible flow line 203 comprises a flexible pipe, wholly or in part, resting on the sea floor 204 or buried below the sea floor and used in a static
15 application. The floating facility may be provided by a platform and/or buoy or, as illustrated in Figure 2, a ship. Any such floating facility may be used, and as used herein the term "vessel" is used to encompass any floating facility. The riser 200 is provided as a flexible riser, that is to say a flexible pipe connecting the ship to the sea floor installation. Here, the flexible pipe includes five segments of flexible pipe body
20 205₀ to 205₄ and four junctions between adjacent segments of pipe body. At each junction, a buoyancy aid 206₀ to 206₃ is attached in some way to the flexible pipe to give uplift to the pipe and reduce the tension loading along the pipe length. This configuration is sometimes known as a Stepped riser configuration.

During use, the configuration of the riser may change due to vessel motion on
25 the sea surface, and momentum built up in the riser from previous movement. This causes tension in the riser to vary. A Stepped riser typically has a longer service life as a result of reduced top tension and reduced top tension variation.

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If the buoyancy aid 206₀ is placed too close to the vessel for the purpose of reducing the top tension to a desirable low level, then the flexible pipe body 205₀ could be subjected to slacking loads and spike loads (i.e. excessively low tension or compression, and excessively high tension, respectively). When, for example, the

5 buoyancy aid 206₀ is moving in an upwards direction (by momentum from a previous movement), while at the same time a movement of the vessel pushes the riser in a downwards direction, this can result in compression forces or slacking of the flexible pipe body 205₀. In subsequent motion, the flexible pipe body 205₀ can then be subjected to a spike tension, which can be of a magnitude higher than the normal tension load. In

10 addition, the flexible pipe body 205₀ becoming slack to the point of diverting from its generally linear configuration and forming a protrusion with high angles of curvature (such as an omega-shaped protrusion). Such curvature may be harmful to the structure of the riser by overbending.

In so called “sour” service environments, that is, when the production fluids

15 contain relatively high concentrations of hydrogen sulphide gas (H₂S) in solution or in gaseous form, the H₂S and other gas species such as CO₂ can permeate through the pipe’s fluid retaining layer into annulus regions defined between layers of the flexible pipe body. Layers of the flexible pipe are thus subject to relatively acidic conditions. In such conditions, a known technique is to use “sour service materials” for potentially

20 vulnerable components of the flexible pipe. This typically involves the use of a wire that has undergone hot/cold working during manufacture, and/or has had corrosion resistant additives added. The sour wires are also weaker than so called sweet wires (for use in non-acidic environments). As such, when using sour service wires, larger wires are needed to ensure a pipe structure having sufficient strength capacity. Larger wires

25 used in the pipe structure will increase the pipe weight, and increased pipe weight will result higher tension load (and so on creating a vicious circle).

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It is an aim of the present invention to at least partly mitigate the above-mentioned problems.

It is an aim of embodiments of the present invention to provide an arrangement that is more capable of withstanding excessive vessel motion on the sea surface.

5 It is an aim of embodiments of the present invention to provide an arrangement that is more capable of reducing the tension and tension variation in a riser to a level at or below a desirably low level, without introducing potential slack or spike loads.

It is an aim of embodiments of the present invention to provide a riser assembly in which tension load can be proactively controlled.

10 It is an aim of embodiments of the present invention to provide a riser assembly that is relatively cost effective to produce with a low installation cost and risk.

According to a first aspect of the present invention there is provided a riser assembly for transporting fluids from a location deep under water, comprising:

15 a riser having a plurality of buoyancy elements provided at predetermined intervals along the length of the riser for supporting the riser, and at least one further buoyancy element arranged to support the riser in a configuration for accommodating tension changes in the riser due to vessel movement.

According to a second aspect of the present invention there is provided a method of providing a riser assembly for transporting fluids from a location deep under water,
20 comprising:

providing a riser having a plurality of buoyancy elements provided at predetermined intervals along the length of the riser for supporting the riser, and at least one further buoyancy element arranged to support the riser in a configuration for accommodating tension changes in the riser due to vessel movement.

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Certain embodiments of the invention provide the advantage that potential shaking loads on the riser brought on by excessive vessel motion are reduced or eliminated from at least greater part of the riser assembly configuration. The shaking loads may be of a magnitude higher than normal tension loads experienced by the riser.

- 5 Certain embodiments of the invention reduce or eliminate potential shaking loads from the entire riser assembly configuration.

Certain embodiments of the invention provide the advantage that tension load on the riser induced by the weight of the riser can be reduced.

- 10 Certain embodiments of the invention provide the advantage that a riser assembly for deep and ultra-deep water application is provided that can be installed relatively quickly and at relatively low cost compared to known configurations.

BRIEF DESCRIPTION OF THE DRAWINGS

- Embodiments of the invention are further described hereinafter with reference to
15 the accompanying drawings, in which:

Figure 1 illustrates a flexible pipe body;

Figure 2 illustrates a known riser assembly; and

Figure 3 illustrates a riser assembly of the present invention.

- 20 Figures 4 is a flowchart illustrating a method, according to one embodiment of the invention.

In the drawings like reference numerals refer to like parts.

DETAILED DESCRIPTION

- Throughout this description, reference will be made to a flexible pipe. It will be
25 understood that a flexible pipe is an assembly of a portion of a pipe body and one or more end fittings in each of which a respective end of the pipe body is terminated.

Figure 1 illustrates how pipe body 100 is formed in accordance with an embodiment of the present invention from a combination of layered materials that form a pressure-containing conduit. Although a number of particular layers are illustrated in Figure 1, it

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is to be understood that the present invention is broadly applicable to coaxial pipe body structures including two or more layers manufactured from a variety of possible materials. It is to be further noted that the layer thicknesses are shown for illustrative purposes only.

5 As illustrated in Figure 1, a pipe body includes an optional innermost carcass layer 101. The carcass provides an interlocked construction that can be used as the innermost layer to prevent, totally or partially, collapse of an internal pressure sheath 102 due to pipe decompression, external pressure, and tensile armour pressure and mechanical crushing loads. It will be appreciated that certain embodiments of the
10 present invention are applicable to 'smooth bore' operations (i.e. without a carcass) as well as such 'rough bore' applications (with a carcass).

 The internal pressure sheath 102 acts as a fluid retaining layer and comprises a polymer layer that ensures internal fluid integrity. It is to be understood that this layer may itself comprise a number of sub-layers. It will be appreciated that when the
15 optional carcass layer is utilised the internal pressure sheath is often referred to by those skilled in the art as a barrier layer. In operation without such a carcass (so-called smooth bore operation) the internal pressure sheath may be referred to as a liner.

 An optional pressure armour layer 103 is a structural layer with a lay angle close to 90° that increases the resistance of the flexible pipe to internal and external pressure
20 and mechanical crushing loads. The layer also structurally supports the internal pressure sheath, and typically consists of an interlocked construction.

 The flexible pipe body also includes a first tensile armour layer 105 and optional second tensile armour layer 106. Each tensile armour layer is a structural layer with a lay angle typically between 10° and 55°. Each layer is used to sustain tensile loads and
25 internal pressure. The tensile armour layers are often counter-wound in pairs.

 The flexible pipe body shown also includes optional layers of tape 104 which help contain underlying layers and to some extent prevent abrasion between adjacent layers.

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The flexible pipe body also typically includes optional layers of insulation 107 and an outer sheath 108, which comprises a polymer layer used to protect the pipe against penetration of seawater and other external environments, corrosion, abrasion and mechanical damage.

5 Each flexible pipe comprises at least one portion, sometimes referred to as a segment or section of pipe body 100 together with an end fitting located at at least one end of the flexible pipe. An end fitting provides a mechanical device which forms the transition between the flexible pipe body and a connector. The different pipe layers as shown, for example, in Figure 1 are terminated in the end fitting in such a way as to
10 transfer the load between the flexible pipe and the connector.

It will be appreciated that there are different types of riser, as is well-known by those skilled in the art. Embodiments of the present invention may be used with any suitable type of riser, such as vertical risers and catenary risers.

Figure 3 shows a riser assembly 300 according to an embodiment of the present
15 invention. The riser assembly 300 includes a riser 302 formed of flexible pipe, and a number of buoyancy modules 304₁₋₇ attached to the riser at various positions.

The riser assembly configuration partly follows the shape of a Stepped riser configuration, with buoyancy modules 304₆₋₇ periodically spaced along the riser 302 to take the weight of the riser. The number of, and distance between, the buoyancy
20 modules will of course vary depending on the length and weight of the riser, and can be determined by a person skilled in the art. This section of the riser assembly can be generally vertical so as to minimize weight and material cost.

In a region of the riser assembly generally close to the top end of the riser 302, there are provided a number of buoyancy modules 304₁₋₅ that are attached to the riser
25 such that the riser forms a Wave configuration below the surface of the water. A Wave configuration is a term known in the art and includes a sag bend (a U-shaped bend) and a hog bend (an inverted U-shaped bend).

The wave section is designated here to tolerate large vessel heave motion without introducing any shaking tension load.

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Wave configurations are usually used only in shallow water applications, for allowing a vessel to have a greater distance of deviation from where a riser contacts the seabed. Wave configurations are considered uneconomical for deep water and ultra-deep water applications, because they require a greater pipe length requiring more materials, and require much larger buoyancy modules or a greater number of buoyancy modules to support the greater length and weight of flexible pipe. Also, for deep water, a Stepped configuration that is generally vertical enables a ship to deviate a fair degree from the touchdown position on the seabed, because of the long pipe length creating a large arc radius, and so a wave configuration is considered unnecessary.

10 Aptly, as shown in Figure 3, the section of riser for attaching to the vessel is relatively short, such that the first buoyancy module from the top end of the riser assembly forms part of the wave section. The section of riser at the hog bend may lie between around 5 and 500 metres from a base of the vessel, aptly between around 5 and 300 metres, and more aptly between 5 and 150 metres. Of course the distance of the
15 hog bend from the surface, and thus the length of the section of riser for attaching to the vessel, will depend on the weight and dimensions of the riser, vessel depth, etc. and can be determined by a person skilled in the art. It is generally preferable for the wave section to be provided close enough to the surface to minimise the top tension loads, yet far enough from the surface that the buoyancy modules do not accidentally pop up to
20 the surface or come into contact with the vessel.

With the above mentioned configuration, the sag bend of the waved section will accommodate changes in the tension of the riser portion close to the vessel, as the sag bend would be raised, lowered, or moved laterally, in line with a corresponding movement of the vessel, while the buoyancy modules at the hog bend would generally
25 hold the riser in a stable position relative to the surface.

The waved section therefore in effect creates two separate sections of the riser, one section for attaching to a vessel, and one section that is independent from movement of the vessel, which can be supported in a Stepped configuration.

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Therefore, in a rough sea, for example, if the vessel experiences excessive movement, which would usually translate to a shaking load on the riser top section, this movement is absorbed by the waved section and is not transferred to the entire length of the riser.

5 In general, the top end of the riser, the point where the riser is attached to a vessel, can be the part of the riser that receives the highest tension loading, due to it taking the highest weight of riser. This is sometimes referred to as the top tension. The riser assembly of the present invention helps to ensure that the top tension remains below a predetermined value that would damage the riser.

10 In addition, the tension in the riser assembly may be proactively controlled by a skilled person to be suitable for a specific use by placing the appropriate buoyancy modules at the appropriate positions along the riser. A skilled person can also determine the amount of buoyancy required to optimize the tension load on the sections of riser.

15 With the above-described assembly, there is provided a riser assembly suitable for deep and ultra-deep water use, which is a cost effective way of managing tension loading. The assembly is cost effective both in terms of onshore fabrication costs (using minimum pipe length and buoyancy modules that are relatively cost effective compared to other means), and offshore installation costs. The assembly may also be
20 used for dealing with highly sour service conditions, which requires a heavy pipe design (with higher top tension load).

FIG. 4 illustrates a method, according to one embodiment, which includes providing a riser having a plurality of buoyancy elements provided at predetermined intervals along the length of the riser for supporting the riser, and at least one further
25 buoyancy element arranged to support the riser in a configuration for accommodating tension changes in the riser due to vessel movement. The method can optionally include transporting fluid(s) (e.g., oil, gas, and/or water) from a location deep under water to a vessel on the water surface via the riser.

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Various modifications to the detailed designs as described above are possible. For example, it will be realised that the number of buoyancy modules used may be varied to suit the specific conditions of use. In addition, the relative positions of the buoyancy modules may vary from that shown in Figure 3, as long as the general principle of accommodating tension changes in the riser due to vessel movement is achieved. For example, the wave configuration may be provided relatively closer to the vessel, or closer to the sea bed, depending on the riser dimensions, weight, type of water body that the riser assembly will be used in, etc.

The buoyancy modules may be attached by any known means to the riser, such as attachment to a rigid buoyancy support between sections of flexible pipe. The buoyancy modules may be any suitable structure for providing buoyancy to the riser, such as metal cans filled with air for example, or other such structure.

In addition, rather than using a plurality of buoyancy modules to create the sag bend near the vessel, a single, larger buoyancy module could be employed. However, in general, smaller buoyancy modules are more cost effective to use.

Throughout the description and claims of this specification, the words “comprise” and “contain” and variations of them mean “including but not limited to”, and they are not intended to (and do not) exclude other moieties, additives, components, integers or steps. Throughout the description and claims of this specification, the singular encompasses the plural unless the context otherwise requires. In particular, where the indefinite article is used, the specification is to be understood as contemplating plurality as well as singularity, unless the context requires otherwise.

Features, integers, characteristics, compounds, chemical moieties or groups described in conjunction with a particular aspect, embodiment or example of the invention are to be understood to be applicable to any other aspect, embodiment or example described herein unless incompatible therewith. All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are

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mutually exclusive. The invention is not restricted to the details of any foregoing embodiments. The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any
5 method or process so disclosed.

The reader's attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

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We claim:

1. A riser assembly for transporting fluids from a location deep under water, comprising:
 - 5 a riser having a plurality of buoyancy elements provided at predetermined intervals along the length of the riser for supporting the riser, and at least one further buoyancy element arranged to support the riser in a configuration for accommodating tension changes in the riser due to vessel movement.
- 10 2. A riser assembly according to claim 1, wherein the at least one further buoyancy element is provided to form a sag bend, in use.
3. A riser assembly according to claim 1 or 2, wherein the at least one further buoyancy element is provided to form a waved configuration, in use.
- 15 4. A riser assembly according to any preceding claim, wherein the riser comprises a first section, a second section and a third section provided in series, and wherein the first section is for attachment to a vessel on a sea surface, the second section comprises the at least one further buoyancy element, and the third section
 - 20 comprises the plurality of buoyancy elements.
5. A riser assembly according to claim 4, wherein the first section is relatively shorter than the third section.
- 25 6. A riser assembly according to claim 3, wherein the waved configuration comprises a sag bend and a hog bend, and in use the portion of riser at the hog bend lies between 5 and 500 metres from a base of the vessel.

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7. A riser assembly according to claim 6, wherein in use the portion of riser at the hog bend lies between 5 and 300 metres from a base of the vessel.

8. A riser assembly according to claim 7, wherein in use the portion of riser
5 at the hog bend lies between 5 and 150 metres from a base of the vessel.

9. A method of providing a riser assembly for transporting fluids from a location deep under water, comprising:

providing a riser having a plurality of buoyancy elements provided at
10 predetermined intervals along the length of the riser for supporting the riser, and at least one further buoyancy element arranged to support the riser in a configuration for accommodating tension changes in the riser due to vessel movement.

10. A method according to claim 9, further comprising providing the at least
15 one further buoyancy element to form a sag bend, in use.

11. A method according to claim 9 or 10, further comprising providing the at least one further buoyancy element to form a waved configuration, in use.

20 12. A method according to any of claims 9 to 11, wherein the riser comprises a first section, a second section and a third section provided in series, and wherein the first section is for attachment to a vessel on a sea surface, the second section comprises the at least one further buoyancy element, and the third section comprises the plurality of buoyancy elements.

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13. A method according to claim 12, wherein the first section is relatively shorter than the third section.

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14. A method according to claim 11, wherein the waved configuration comprises a sag bend and a hog bend, and in use the portion of riser at the hog bend lies between 5 and 500 metres from a base of the vessel.

5 15. A method according to claim 14, wherein in use the portion of riser at the hog bend lies between 5 and 300 metres from a base of the vessel.

16. A method according to claim 15, wherein in use the portion of riser at the hog bend lies between 5 and 150 metres from a base of the vessel.

10

17. A riser assembly substantially as herein described with reference to the drawings.

18. A method substantially as herein described with reference to the
15 drawings.

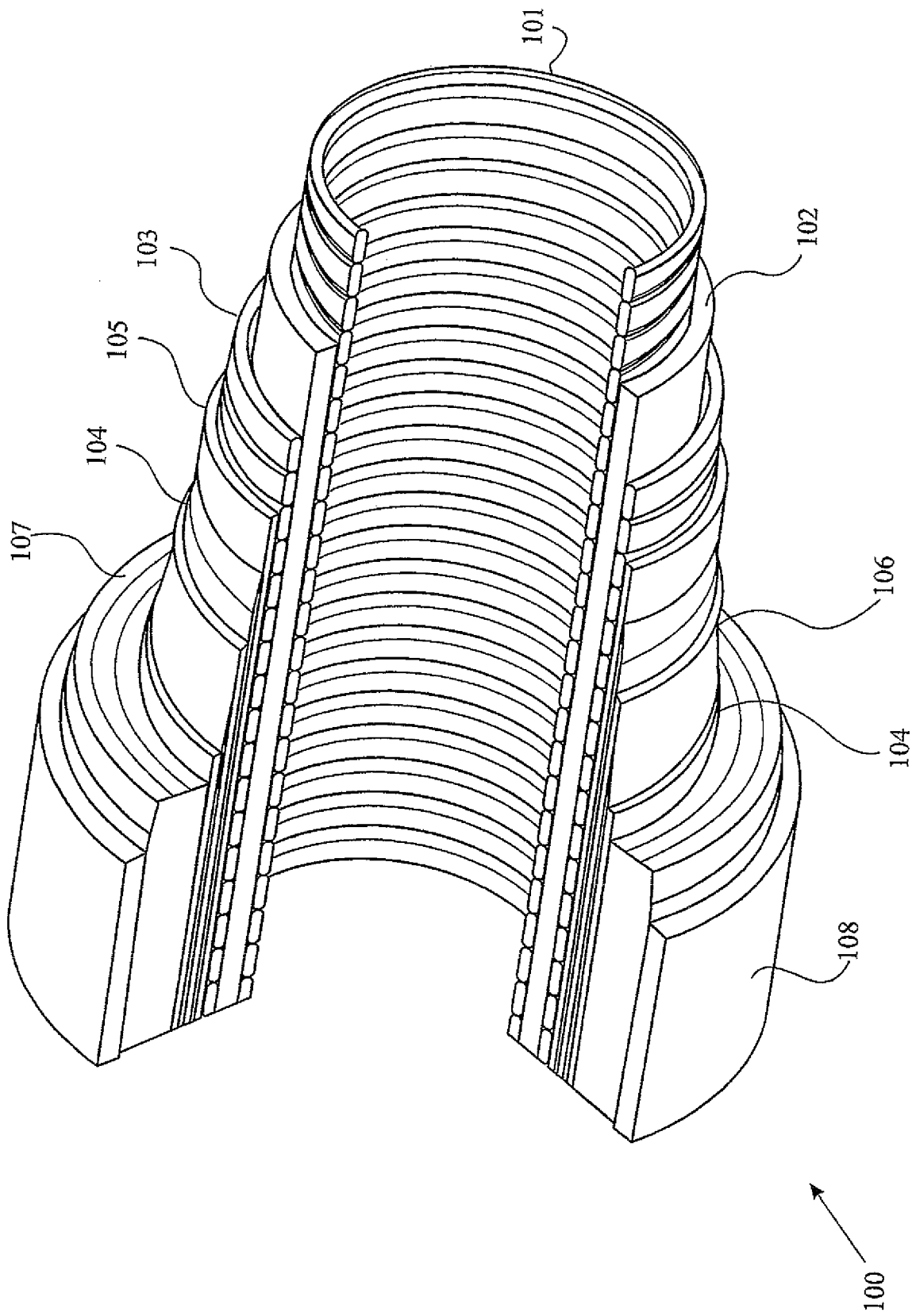


Fig. 1

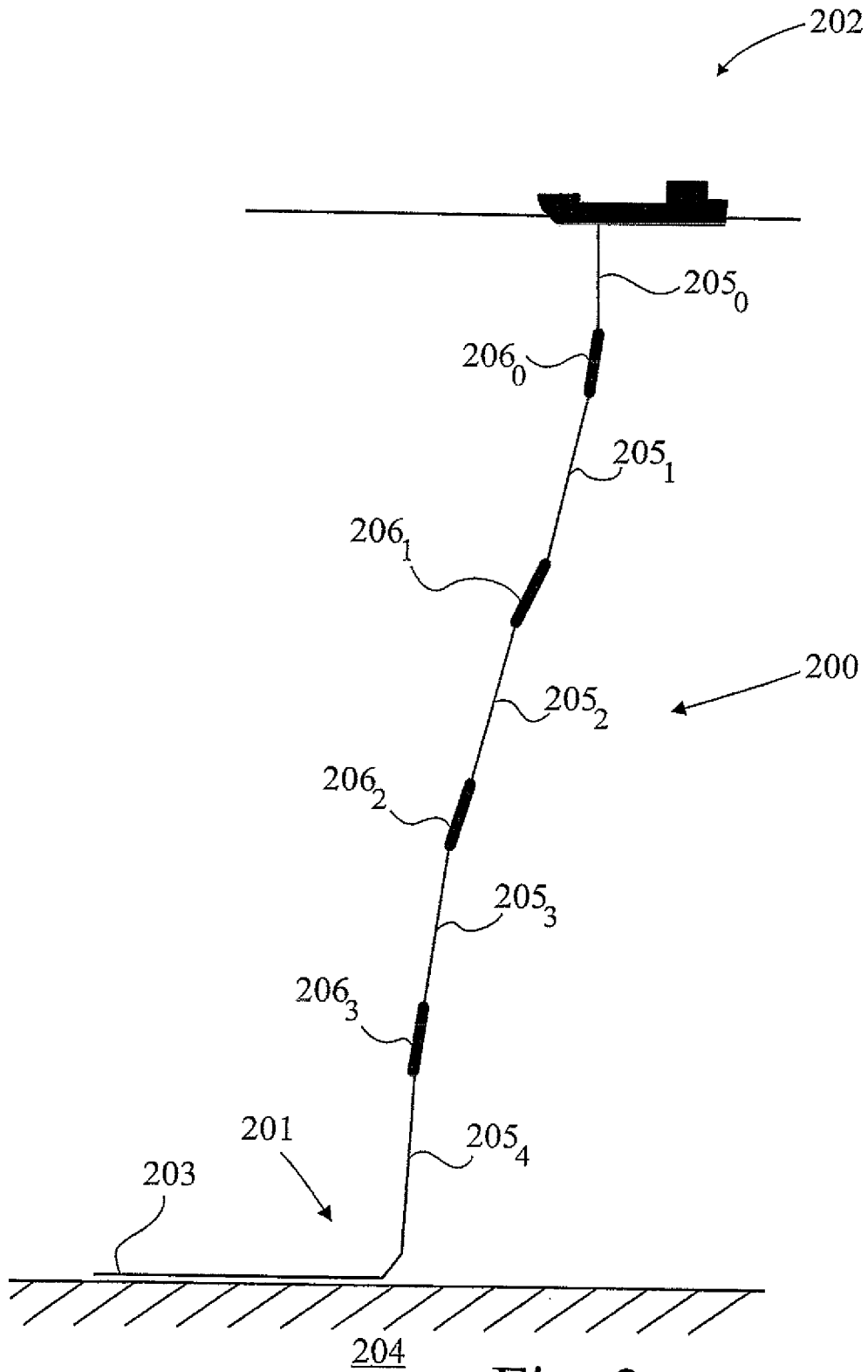
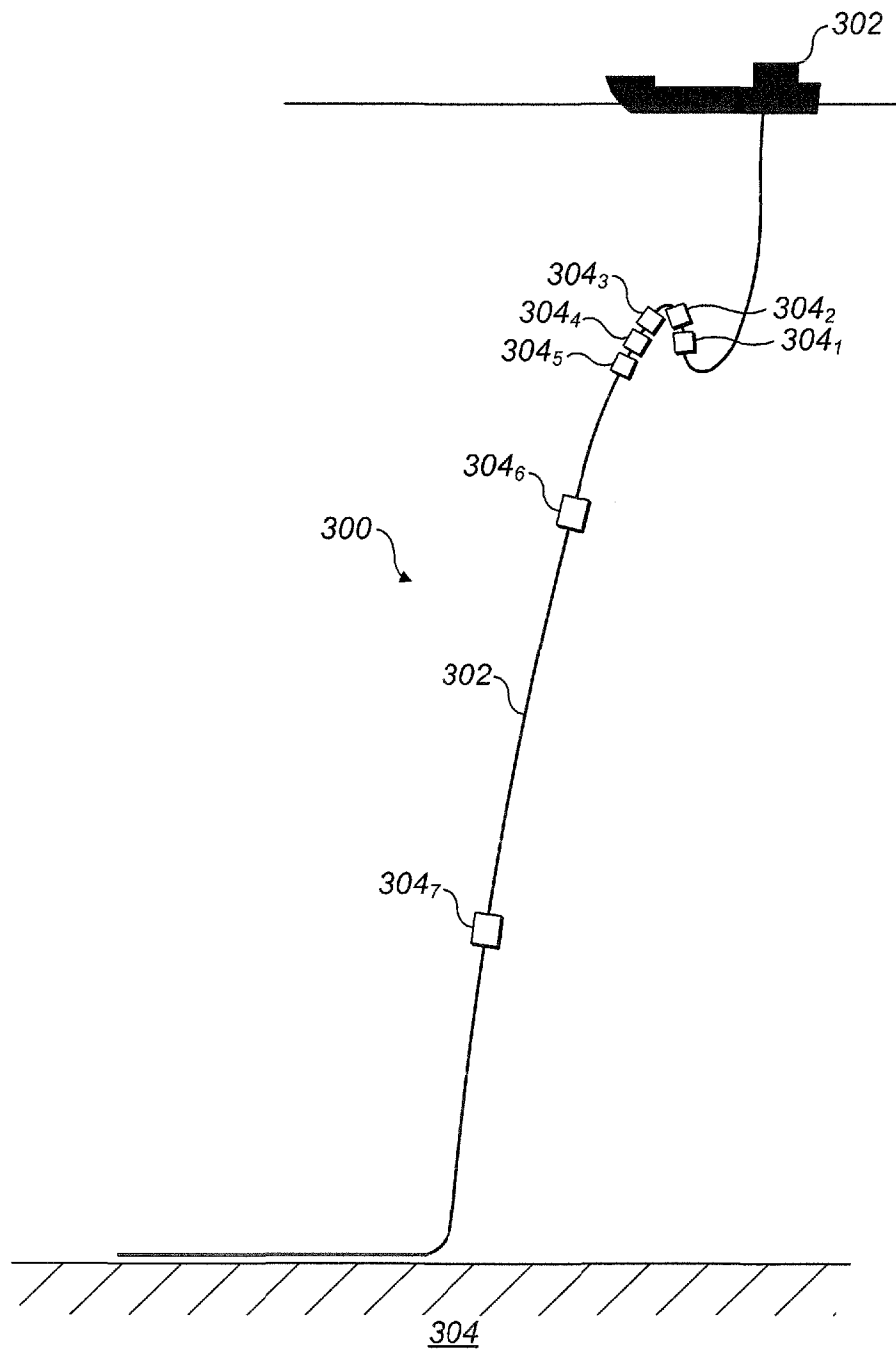
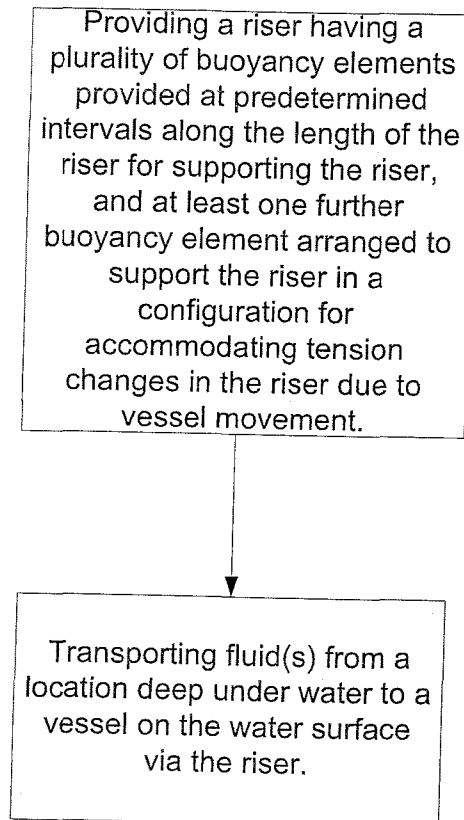


Fig. 2

**FIG. 3**

**Fig. 4**