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WO 2009/146710 A1 **WO 2008/053142 A2**
WO 2004/085905 A1 **US 6923477 B2**
US 6412825 B1

(58) Field of Search:
INT CL **E21B, F16L, G01M**
Other: **EPODOC, WPI**

(54) Title of the Invention: **Integrity monitoring of sectioned hoses**
Abstract Title: **A flexible riser having sections, each with a conduit and an annulus sealed from the other sections and a integrity monitoring device**

(57) A flexible line or riser installed between a platform and a subsea structure. The flexible line featuring a plurality of pairwise coupled tubular sections including a first section 200. At least one of the plurality of sections is disposed between the first section and the platform. The first section also features a conduit 204 for transporting fluid between the subsea structure and the platform and an annulus 206 surrounding the conduit. An access device 210 configured to provide fluid communication between the annulus and a measurement device for integrity monitoring of the first section is provided. Where the annulus is sealed to prevent fluid communication between the annulus and any annulus of an adjacent section of the flexible line. Optionally, the first section features an end fitting at each end of the first section. Optionally, there is a cable or hose 212 coupled to the access device for providing fluid communication between the annulus and the measurement device.

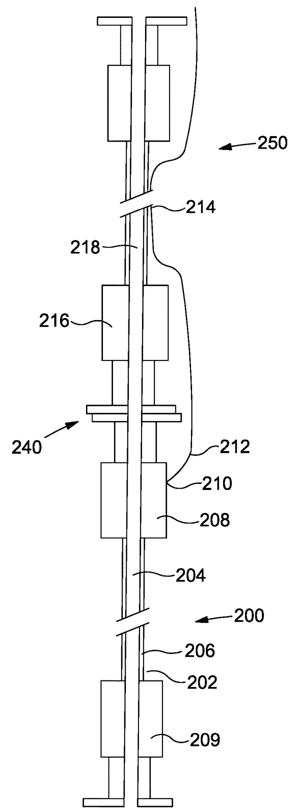

Figure 2A

GB 2568898 A

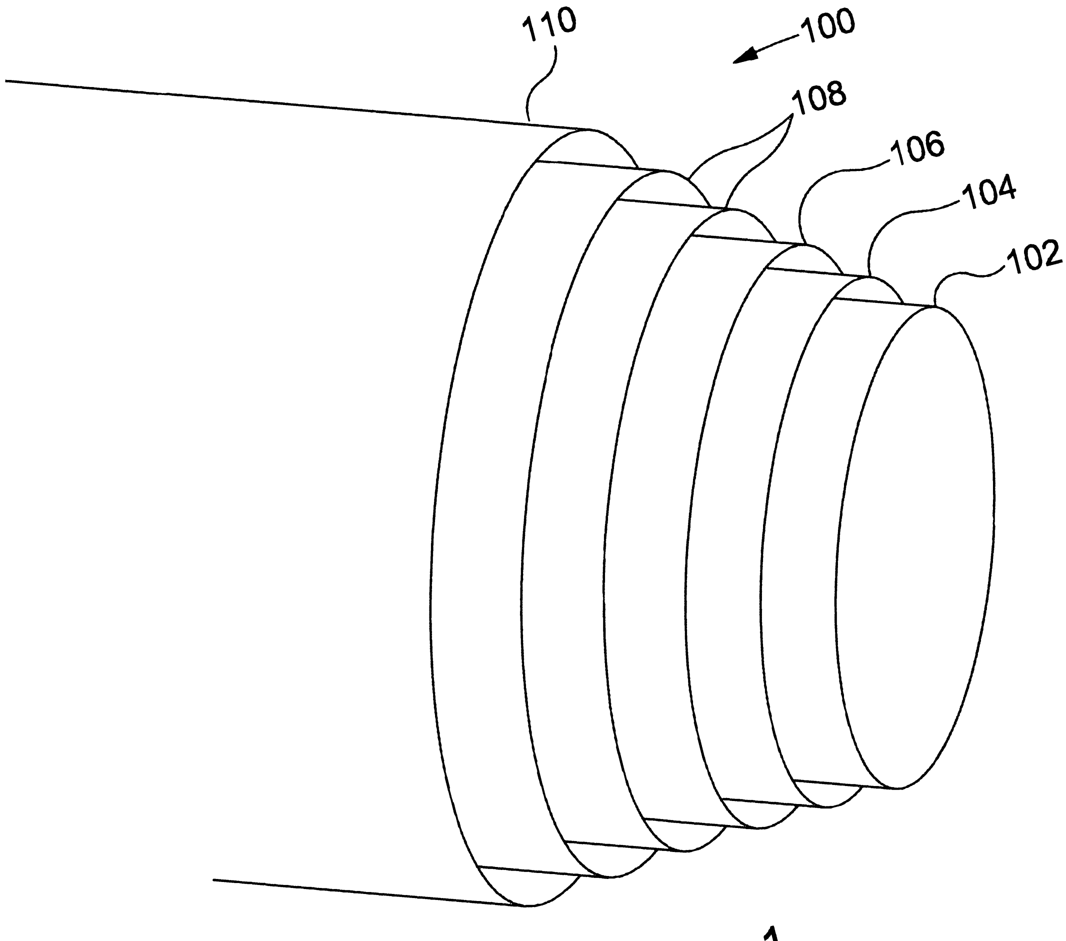

Figure 1

29 01 18

29 01 18

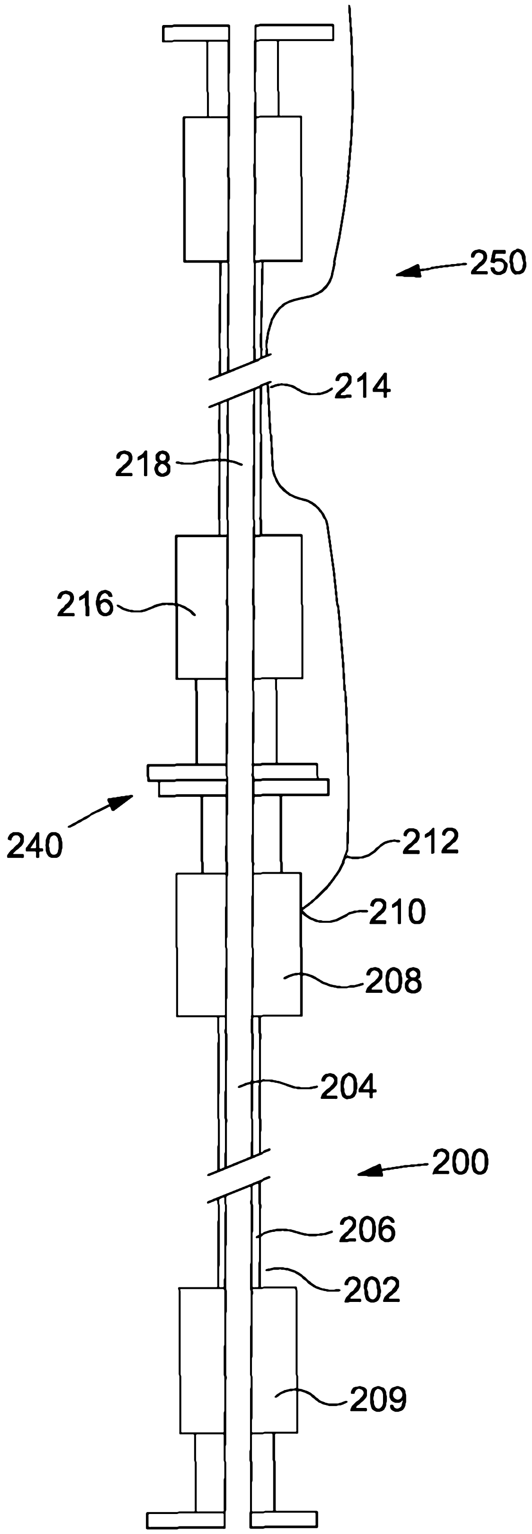

Figure 2A

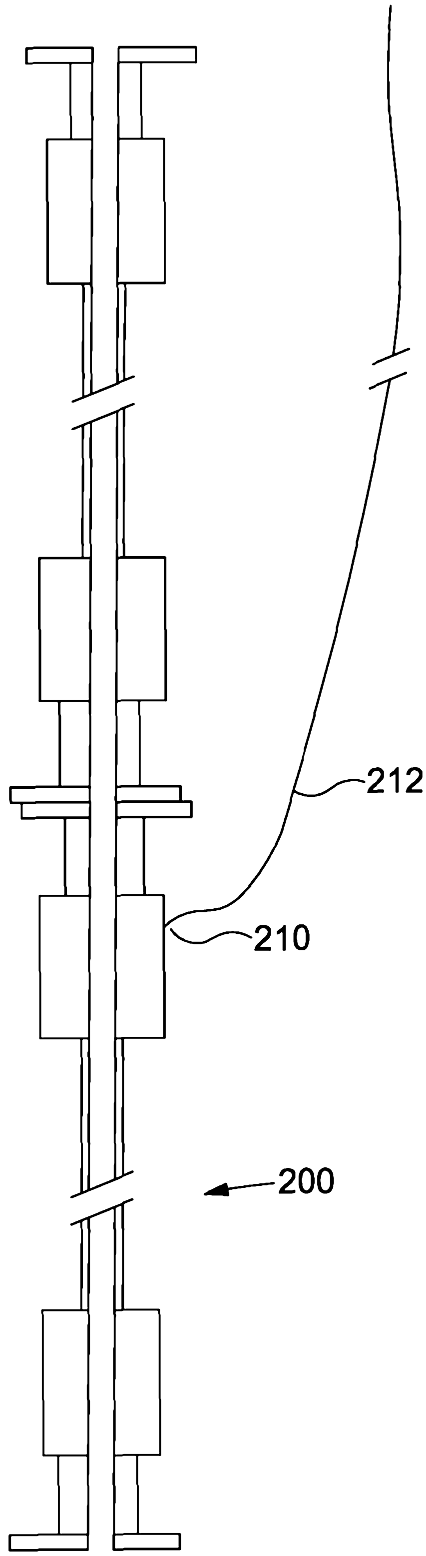

Figure 2B

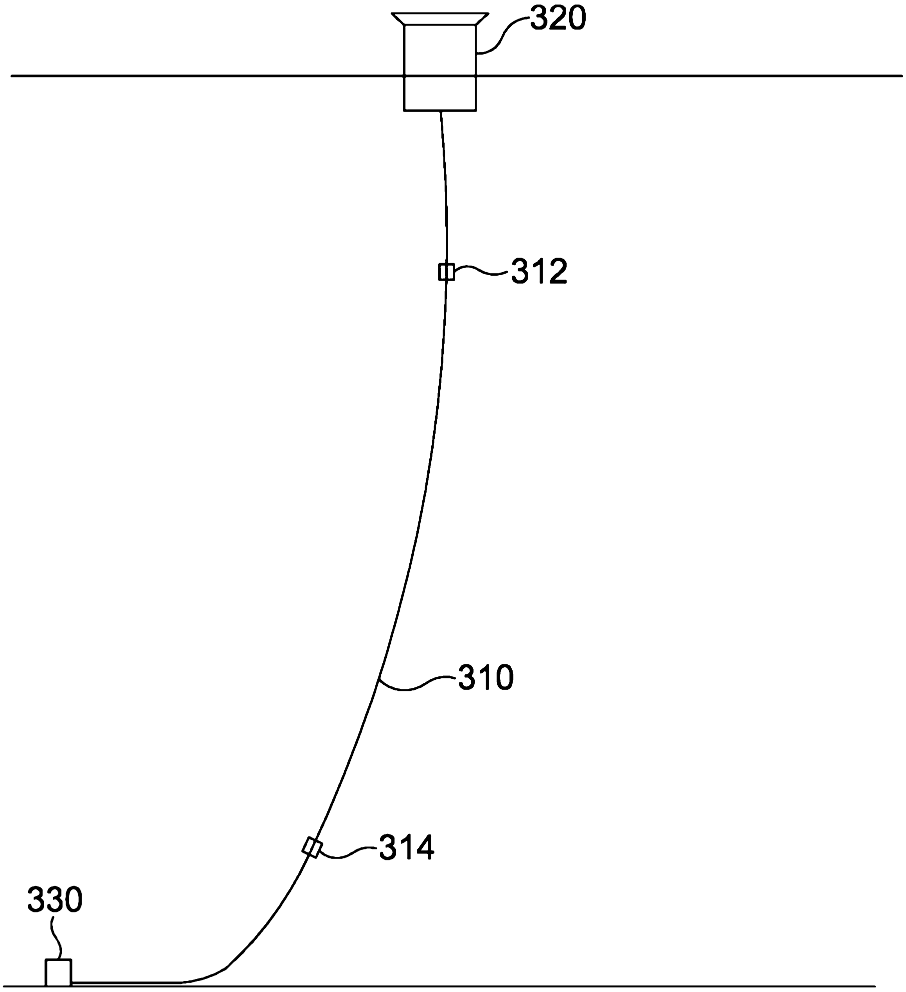

Figure 3

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29 01 18

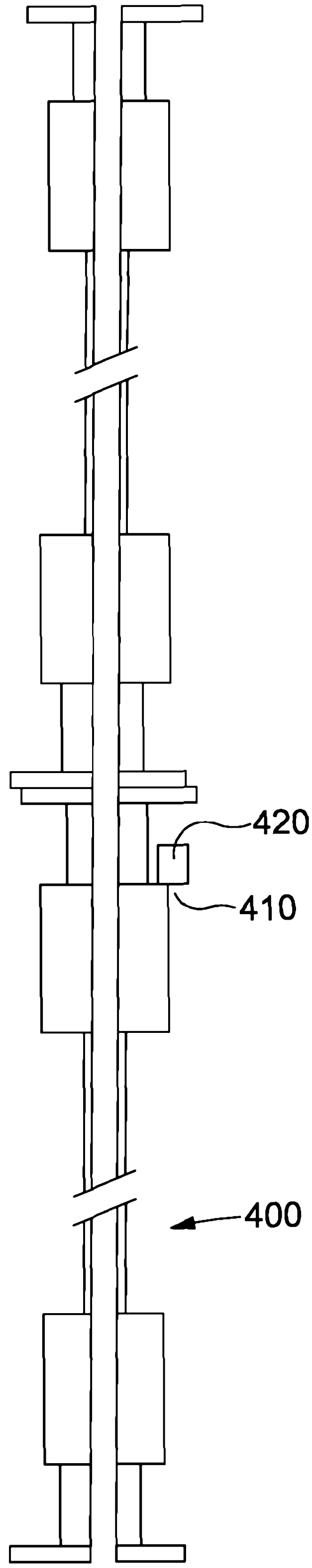

Figure 4

INTEGRITY MONITORING OF SECTIONED HOSES

Technical Field

The present invention relates to the integrity monitoring of sectioned hoses, and in particular the in situ integrity monitoring of a lower riser section of a flexible unbonded riser comprising multiple riser sections.

Background

In the context of offshore hydrocarbon production, a riser is a tubular conduit that extends from a subsea structure to a production platform such as a floating unit, for the purpose of conveying produced hydrocarbons from a well to the platform and/or conveying injection fluids from the production platform to the well. The subsea structure may be a “christmas tree”, riser base, Blowout Preventer (BOP), or some other structure.

Flexible risers are configured in order to allow for movements of the platform relative to the subsea structure in both a horizontal and a vertical direction, and for the effects of ocean currents on the riser itself. Flexible risers are particularly important for deep water wells, where the water depth may be more than 1000 m, and up to 2000-3000 m. In deep water applications a flexible riser may be made up of multiple riser sections joined in series. This sectioning of the riser means that the shorter riser sections can be stored more easily (for example on a reel) before installation, and allows for optimisation of the properties of each riser section to account for different conditions at varying depths.

As shown in Figure 1, the cross-section of a flexible riser 100 typically comprises multiple layers including metallic and polymeric materials. Such multiple layers typically include a metallic inner carcass layer 102, an inner polymer layer 104 referred to as a pressure sheath or pressure liner, and an outer polymer layer 110 referred to as an external sheath or outer sheath. A volume between the inner polymer layer and the outer polymer layer of a flexible riser is referred to as the annulus. Further layers between the inner and outer polymer layers may include pressure vault 106 and tensile armour 108 layers. In a bonded flexible riser the layers are joined together such that relative movement of the layers is restricted. In an unbonded flexible riser the layers are not fastened or joined together and the layers are therefore more free to move relative to one another.

It is necessary to monitor the condition of a flexible riser over its lifetime, including the period in which a riser approaches the end of (or exceeds) its intended service lifetime. Such monitoring aims to determine if the integrity of the pipe layers is challenged or has been breached, due to factors such as pressure, temperature or a corrosive environment. Integrity monitoring of flexible risers can be achieved by, for example, using a remotely operated underwater vehicle (ROV) to perform a visual inspection, or by performing annulus monitoring. Such annulus monitoring may comprise measurement of a volume of gas in the annulus, since a breach in the outer layer of the flexible riser may result in water entering the annulus, meaning that the free annulus volume is less than expected. Alternatively or additionally, the gas composition may be measured to determine if the gas composition has changed due to diffusion through, or a breach in, the inner polymer layer.

Summary

It is an object of the present invention to facilitate access to an annulus of a lower flexible riser section for integrity monitoring purposes.

In accordance with a first aspect of the present invention there is provided a flexible line installed between a platform and a subsea structure. The flexible line comprises a plurality of pairwise coupled tubular sections including a first section, wherein at least one of the plurality of sections is disposed between the first section and the platform. The first section comprises a conduit for transporting fluid between the subsea structure and the platform; an annulus surrounding the conduit; and an access device configured to provide fluid communication between the annulus and a measurement device for integrity monitoring of the first section, wherein the annulus is sealed to prevent fluid communication between the annulus and any annulus of an adjacent section of the flexible line.

The first section may comprise an end fitting at each end of the first section.

The plurality of pairwise coupled tubular sections may be located underwater.

The flexible line may further comprise a cable or hose coupled to the access device for providing fluid communication between the annulus and the measurement device. The cable or hose may be permanently coupled to the access device; alternatively, the cable or hose may be removably coupled to the access device. The cable or hose may be externally attached to a section between the first section and the platform. The cable or hose may be free hanging between the access device and the platform or the measurement device.

The measurement device may be mounted externally on the first section or a section adjacent to the first section.

The access device may comprise a port providing fluid access to the annulus from an outside of the first section.

The access device may comprise a valve configured to selectively provide fluid communication between the annulus and the measurement device.

The access device may be located in one of the end fittings of the first section. Alternatively, the access device may be located in a wall portion of the first section between the end fittings.

In accordance with a second aspect of the present invention there is provided a method of accessing an annulus of a first section of a flexible line installed between a platform and a subsea structure. The flexible line comprises a plurality of sections, wherein at least one of the plurality of sections is disposed between the first section and the platform. The first section comprises: a conduit for transporting fluid between the subsea structure and the platform; an annulus surrounding the conduit; and an access device configured to provide fluid communication between the annulus and an apparatus for integrity monitoring of the first section, wherein the annulus is sealed to prevent fluid communication between the annulus and any annulus of an adjacent section of the flexible line. The method comprises using the access device to provide fluid communication between the annulus and a measurement device.

The first section may comprise an end fitting at each end of the first section.

The plurality of pairwise coupled tubular sections may be located underwater.

Using the access device may comprise using a cable or hose coupled to the access device to provide fluid communication between the annulus and the measurement device. The cable or hose may be permanently coupled to the access device. Alternatively, the cable or hose may be removably coupled to the access device. The cable or hose may be externally attached to a section between the first section and the platform; alternatively, the cable or hose may be free hanging between the access device and the platform or the measurement device.

The measurement device may be mounted externally on the first section or a section adjacent to the first section.

The access device may comprise a port providing fluid access to the annulus from an outside of the first section.

The access device may comprise a valve, and the using the access device may comprise using the valve to selectively provide fluid communication between the annulus and the measurement device.

The access device may be located in one of the end fittings of the first section. Alternatively, the access device may be located in a wall portion of the first section between the end fittings.

In accordance with an aspect of the invention there is provided a method of monitoring the integrity of an annulus of a first section of a flexible line installed between a platform and a subsea structure, the flexible line comprising a plurality of sections including said first section, wherein at least one of the plurality of sections is disposed between the first section and the platform. The method comprises coupling a measurement device to an annulus of the first section which surrounds a conduit of the first section, via an access device of the first section in fluid communication with the annulus, wherein the annulus is sealed to prevent fluid communication between the annulus and any annulus of an adjacent section of the flexible line. The method may further comprise using the measurement device to monitor the integrity of the annulus of the first section. The measurement device may be used to detect properties of a gas within the annulus, e.g. pressure, gas composition, temperature, leakage.

Brief Description of the Drawings

Figure 1 shows the layered structure of a flexible riser in accordance with the prior art.

Figure 2A shows a lower section and an upper section of a flexible riser in accordance with the invention, with a cable or hose attached to a section of the flexible riser.

Figure 2B shows a lower section and an upper section of a flexible riser in accordance with the invention, with a free-hanging cable or hose.

Figure 3 shows a sectioned flexible riser installed between a platform and a subsea structure.

Figure 4 shows a lower section and an upper section of a flexible riser in accordance with the invention, with a measurement apparatus attached to a section of the flexible riser.

Detailed Description

As set out above, integrity management of a flexible riser is necessary to confirm that the performance of a flexible riser is within operational requirements. In particular, the integrity of a flexible riser is monitored to determine whether a layer (or layers) of the flexible riser has been challenged or breached, or has failed in any way.

Monitoring using an ROV provides a visual inspection. Annulus monitoring is typically performed using topside measurements, wherein the annulus of a flexible riser is accessed via a topmost portion of the flexible riser for measuring annulus volume and/or gas composition, and measuring apparatus on a platform, for example a floating unit, is used. Such topside measurements do not provide for the full, in situ integrity monitoring of sectioned risers, because topside techniques only allow access to the annulus of a single, top-most riser section for annulus volume or gas composition determination.

The invention relates to a flexible line installed between a platform and a subsea structure. The flexible line comprises a plurality of pairwise coupled tubular sections including a first section, wherein at least one of the plurality of sections is disposed between the first section and the platform. The first section comprises a conduit for transporting fluid between the subsea structure and the platform, an annulus surrounding the conduit; and an access device configured to provide fluid communication between the annulus and a measurement device for integrity monitoring of the first section. The annulus is sealed to prevent fluid communication between the annulus and any annulus of an adjacent section of the flexible line. The access device provides access to the annulus of the lower section, which is typically not available using topside measurement techniques that provide access only to a topmost riser section. The access to the annulus of the lower section does not require access via an annulus of an upper section. The sealing of the annulus of the lower section means that failure in another section of the riser above or below the lower section (e.g. the ingress of a fluid or fluids) cannot be communicated to the annulus of the lower section.

Figure 2a shows a lower section 200, referred to here sometimes as “a first section” 200, and an upper section 250 of a flexible line. In particular, the lower section 200 and upper section 250 are two adjacent sections of a riser 310 such as a flexible unbonded riser. The riser may comprise other sections above the upper section 250 and/or below the lower section 200. As shown in Figure 3, the riser 310 extends between a platform 320, for example a floating platform at the surface of the sea, and a subsea structure 330, and comprises midline connections 312, 314 joining sections of the riser 310 in series. Figure 3 shows a riser having three sections, but the riser may have any number of sections according to the relevant requirements. The upper section is closer to the platform 320 than the lower section. The lower section and upper section may be located at any position along the riser between the platform 320 and the subsea structure 330. For example, the upper section may be the section of the riser that is closest to the platform 320, the upper section and lower section may be separated from the platform 320 and the subsea structure 330 by other sections, or the lower section may be the section of the riser that is closest to the subsea structure 330. In use the lower section 200 and upper section 250 may be submerged underwater.

The lower section 200 comprises a pipe 202, in particular a flexible unbonded riser pipe having a layered construction which may be in accordance with Figure 1. In particular, the pipe 202 comprises a metallic inner carcass layer 102, an inner polymer layer 104 which may be a pressure sheath or pressure liner, and an outer polymer layer 110 which may be an external sheath or outer sheath, and may comprise further layers between the inner and outer polymer layers, for example armour layers 108 and/or a pressure vault layer 106. A volume within the innermost layer, which may be the carcass layer 102, defines a conduit 204 suitable for transporting fluids from the subsea structure up to the platform. A volume between the inner polymer layer 104 and the outer polymer layer 110 defines an annulus 206. The annulus 206 may be at least partially occupied by layers of material located between the inner polymer layer and the outer polymer layer. The layers of material located between the inner polymer layer and the outer polymer layer may be porous to gases and/or liquids, and may comprise, for example metal wire windings with gaps through which a gas or liquid can pass. When the annulus 206 is in an intact state a remaining volume of the annulus (i.e. a volume of the annulus not occupied by any layers of material between the inner polymer layer and the outer polymer layer) is occupied by a gas or a mixture of gases.

The structure of the upper section 250 is similar to, or even the same as, the structure of the lower section 200, and the upper section performs a function similar to that performed by the lower section. The structure and materials used in the lower section 200 and/or the upper section 250 may be varied to optimise the performance of each section, depending on relevant conditions. For example, if the lower and/or upper sections 200,250 are nearer the top of the riser (i.e. nearer the platform 320), the lower and/or upper sections 200,250 may be optimised to mitigate the effects of high tension in the riser. Further, if the lower and/or upper sections 200,250 are nearer the bottom of the riser (i.e. nearer the subsea structure 330), they may be optimised to mitigate the effects of large hydrostatic pressures.

The lower section 200 further comprises first and second end fittings 208 and 209. The upper section 250 comprises an end fitting 216. The lower section 200 and the upper section 250 are joined together in series using the first end fitting 208 and the end fitting 216 of the upper section. The joint provided by the first end fitting 208 and the end fitting 216 of the upper section 250 is a midline connection 240 (i.e. the first end fitting 208 and the end fitting 216 of the upper section 250 combine to form the midline connection 240). The second end fitting 209 may be connected to a further section of the riser. The conduit 204 and a corresponding conduit 218 of the upper section 250 are joined together in fluid communication to provide a main bore of the riser through the midline connection 240, to facilitate the transport of fluids between the subsea structure and the platform.

An annulus 206 is provided, and is sealed such that no fluid communication is possible between the annulus 206 and a corresponding annulus of the upper section, and between the annulus 206 and an annulus of any further section below the lower section.

Access to the annulus 206 for integrity monitoring purposes is achieved using access device 210. The access device 210 facilitates fluid communication between the annulus and a measurement device, where the measurement device is for performing integrity monitoring measurements. The access device 210 can be located at any convenient location on the lower section 200. Figure 2a shows the access device located at the first end fitting 208. Alternatively, the access device may be located at the second end fitting 209. As a further alternative, the access device may be located at a portion of the lower section 200 between the first end fitting 208 and the second end fitting 209, i.e. in a wall portion of the pipe 202, in which case the access device 210 provides access to the annulus directly through layers of the pipe 202 (such that no access through the first or second end fitting is required).

The access device 210 comprises a port providing access to the annulus for integrity monitoring measurements. In particular, the port provides a fluid transport path between the annulus 206 and any element coupled for the access device (for example, a cable or hose 212 or measurement device 420). In the case that the access device 210 is located in the first or second end fitting 208,209, the port provides the fluid transport path from/to the annulus 206 through the material of the end fitting and through any layers of material of the flexible riser as necessary. In the case that the access device 210 is located at a portion of the lower section 200 between the midline sections, the port provides the fluid transport path through the layers of the pipe 202.

The port may have a varying cross-section and/or may comprise a tube or pipe section if necessary to provide access to the annulus 206.

The access device 210 may comprise a valve that selectively provides fluid communication between the annulus 206 and the measurement device. The valve is located in the port. When the valve is closed, no fluid may exit or enter the annulus 206 via the port. When the valve is open, the fluid transport path is open and fluid can enter or exit the annulus 206 via the port.

As shown in Figure 2a the access device 210 is coupled to one end of a cable or hose 212. Another end of the cable or hose 212 is coupled to the measurement device (not shown), which is located on or near the platform 320, or on a separate service floating unit, for example a service vessel (not shown). The other end of the cable or hose 212 may be coupled to the platform 320 or the separate service vessel, with a further connecting cable or hose completing connection to the measurement device). The cable or hose 212 facilitates transport of signals or data, or a fluid or fluids, respectively, between the annulus 206 and the measurement device. The transport of a fluid of fluids may occur due to inherent conditions in the annulus 206 and cable or hose 212 (for example, a higher or lower pressure in the annulus 206 relative to conditions where the measurement device is located), or the measurement device or other associated apparatus may apply a positive or negative pressure via the cable or hose 212 to produce fluid transport. The cable or hose 212 may be tied or otherwise attached to a portion 214 of the upper section 250, and/or to a portion of one or more further sections between the upper section 250 and the platform 320. Attaching the cable or hose 212 in this way reduces the risk of interference with or damage to the cable or hose 212 as a result of operations carried out in the vicinity of the flexible riser that includes the lower section 200 and upper section 250. Alternatively, as shown in Figure 2b, the cable or hose 212 may be free-hanging between the access device 210 and the measurement device, or between the access device 210 and the platform 320, or between the access device 210 and the separate service vessel.

The cable or hose 212 may be permanently coupled to the access device 210, or may be removably coupled to the access device 210. In the case that the cable or hose 212 is permanently coupled to the access device 210 the fluid transport path between the annulus 206 and the cable or hose 212 may be continuously open, i.e. the port is never closed, or the fluid transport path may be selectively opened or closed using the valve. In the case that the cable or hose 212 is removably coupled to the access device 210 the fluid transport path is closed using the valve when the cable or hose is removed 212. Hence it is not necessary for the cable or hose 212, or any other element, to be coupled to the access device 210 at all times, and a cable or hose coupled to the access device 210 can therefore be replaced by, for example, a new cable or hose, a measurement device, or another element suitable for coupling to the access device 210.

As shown in Figure 4, the measurement device 420 may be coupled directly (either permanently or removably) to the access device 410. Alternatively, the measurement device 420 may be attached to the lower section 400, the upper section 450 or a section adjacent to the lower section. In the case that the measurement device 420 is attached to the lower section 400, the upper section 450 or a section adjacent to the lower section, the measurement device 420 is coupled to a cable or hose (not shown in Figure 4) which is in turn coupled to the access device 410. The measurement device 420 may be in data transmission and receiving communication with a corresponding device (where the corresponding device is located, for example, on the platform) wirelessly, or via a cable (for example the cable 212, or a separate cable bundled with the cable or hose 212) or a wire. The data transmitted may comprise measurement data and the data received may comprise instructions for performing integrity monitoring measurements. Alternatively or additionally, communication with the measurement device 420 may be achieved using an ROV (not shown).

The measurement device performs integrity monitoring measurements by, for example, measuring a volume of gas present in the annulus and comparing the measured gas volume with an expected volume which may correspond to a known volume of the annulus. In this way it is possible to detect a potential breach in an outer layer or layers separating the annulus from the environment surrounding the lower section presence. For example, a measured gas volume that is lower than an expected gas volume may indicate the presence a liquid in the annulus, the liquid having leaked into the annulus through a breach in the layers of the flexible riser and replaced a corresponding volume of gas. Alternatively or additionally the measurement device may measure the gas composition in the annulus. A measured gas composition that does not correspond to the expected gas composition may indicate a breach in a layer or layers of the flexible riser and consequent leakage of a gas or gases into the annulus.

It will be appreciated by the person of skill in the art that various modifications may be made to the above described embodiments without departing from the scope of the present invention.

Claims

1. A flexible line installed between a platform and a subsea structure, the flexible line comprising a plurality of pairwise coupled tubular sections including a first section, wherein at least one of the plurality of sections is disposed between the first section and the platform, the first section comprising:

a conduit for transporting fluid between the subsea structure and the platform;

an annulus surrounding the conduit; and

an access device configured to provide fluid communication between the annulus and a measurement device for integrity monitoring of the first section,

wherein the annulus is sealed to prevent fluid communication between the annulus and any annulus of an adjacent section of the flexible line.

2. A flexible line in accordance with claim 1, wherein the first section comprises an end fitting at each end of the first section.

3. A flexible line in accordance with any one of the preceding claims, wherein the plurality of pairwise coupled tubular sections are located underwater.

4. A flexible line in accordance with any one of the preceding claims, further comprising a cable or hose coupled to the access device for providing fluid communication between the annulus and the measurement device.

5. A flexible line in accordance with claim 4, wherein the cable or hose is permanently coupled to the access device.

6. A flexible line in accordance with claim 4, wherein the cable or hose is removably coupled to the access device.

7. A flexible line in accordance with any one of claims 4 to 6, wherein the cable or hose is externally attached to a section between the first section and the platform.

8. A flexible line in accordance with any one of claims 4 to 6, wherein the cable or hose is free hanging between the access device and the platform or the measurement device.

9. A flexible line in accordance with any one of the preceding claims, wherein the measurement device is mounted externally on the first section or a section adjacent to the first section.

10. A flexible line in accordance with any one of the preceding claims, wherein the access device comprises a port providing fluid access to the annulus from an outside of the first section.

11. A flexible line in accordance with any one of the preceding claims, wherein the access device comprises a valve configured to selectively provide fluid communication between the annulus and the measurement device.

12. A flexible line in accordance with any one of claims 2 to 11, wherein the access device is located in one of the end fittings of the first section.

13. A flexible line in accordance with any one of claims 2 to 11, wherein the access device is located in a wall portion of the first section between the end fittings.

14. A method of monitoring the integrity of an annulus of a first section of a flexible line installed between a platform and a subsea structure, the flexible line comprising a plurality of sections including said first section, wherein at least one of the plurality of sections is disposed between the first section and the platform, the first section comprising:

a conduit for transporting fluid between the subsea structure and the platform;

an annulus surrounding the conduit; and

an access device configured to provide fluid communication between the annulus and a measurement device for integrity monitoring of the first section,

wherein the annulus is sealed to prevent fluid communication between the annulus and any annulus of an adjacent section of the flexible line, the method comprising:

using the access device to provide fluid communication between the annulus and the measurement device.

15. A method in accordance with claim 14, wherein the first section comprises an end fitting at each end of the first section.

16. A method in accordance with any one of claims 14 or 15, wherein the plurality of pairwise coupled tubular sections are located underwater.

17. A method in accordance with any one of claims 14 to 16, wherein using the access device comprises using a cable or hose coupled to the access device to provide fluid communication between the annulus and the measurement device.

18. A method in accordance with claim 17, wherein the cable or hose is permanently coupled to the access device.

19. A method in accordance with claim 17, wherein the cable or hose is removably coupled to the access device.

20. A method in accordance with any one of claims 17 to 19, wherein the cable or hose is externally attached to a section between the first section and the platform.

21. A method in accordance with any one of claims 17 to 19, wherein the cable or hose is free hanging between the access device and the platform or the measurement device.

22. A method in accordance with any one of claims 14 to 21, wherein the measurement device is mounted externally on the first section or a section adjacent to the first section.

23. A method in accordance with any one of claims 14 to 22, wherein the access device comprises a port providing fluid access to the annulus from an outside of the first section.

24. A method in accordance with any one of claims 14 to 22, wherein the access device comprises a valve, and using the access device comprises using the valve to selectively provide fluid communication between the annulus and the measurement device.

25. A flexible line in accordance with any one of claims 15 to 24, wherein the access device is located in one of the end fittings of the first section.

26. A flexible line in accordance with any one of claims 15 to 24, wherein the access device is located in a wall portion of the first section between the end fittings.

Intellectual Property Office

Application No:	GB1719860.7	**Examiner:**	Mr Aquila Brandon-Salmon
Claims searched:	1-26	**Date of search:**	17 April 2018

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-26	WO 2008/053142 A2 (WELLSTREAM INT) See figures 1 and 4 and page 1 lines 18-28
Y	1-26	WO 2009/146710 A1 (NKT FLEXIBLES) See figure 4 and page 21 lines 4-15.
Y	1-26	WO 04/085905 A1 (WELLSTREAM INT) See figures 2 and 3.
Y	1-26	US 6412825 B1 (LANGKJAER) See figures 2 and 3.
Y	1-26	US 6923477 B2 (BUON et al.) See figure 3

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

E21B; F16L; G01M

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI

Intellectual
Property
Office

International Classification:

Subclass	Subgroup	Valid From
E21B	0017/01	01/01/2006
E21B	0017/08	01/01/2006
F16L	0011/12	01/01/2006