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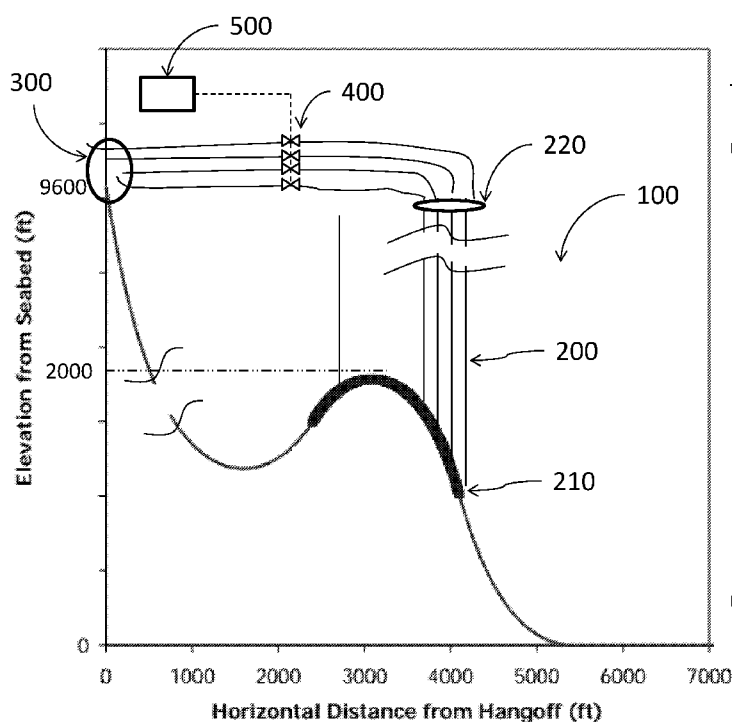


Figure 2

(57) **Abstract:** A riser system for transporting hydrocarbons from a sea bed installation towards a floating installation comprises a Steel Catenary Riser, SCR (100), and at least one flexible flow line (200). The SCR comprises a lower portion (130) having a lower end (104) for fluid communication with a sea bed installation, a middle portion (120) and an upper portion (110) having an upper end (102) for fluid communication with the floating installation. Each flexible flow line has an upper end for communication with the floating installation. The middle portion of the SCR is configured to be supported by at least one buoyancy aid (220) and comprises at least one connector (210) for fluid connection of the SCR to a lower end of each flexible flow line. In use, hydrocarbons being transported from the sea bed installation can flow towards the floating installation through the upper portion of the SCR and through each flexible flow line.



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APPARATUS AND METHOD FOR
TRANSPORTING HYDROCARBONS FROM THE SEABED

The present invention relates to a riser system and method for transporting
5 hydrocarbons from a sea bed installation towards a floating installation.

Hydrocarbons extracted from the sea bed are transported via flexible flow lines, risers, jumpers and the like to surface-level installations, floating installations or transporter vessels such as oil tankers, for example.

Conventionally, risers used in subsea oil installations are known as Steel Lazy-
10 Wave Risers, SLWRs, or Steel Catenary Risers, SCRs, (because of their flexibility and the shape they adopt). The pipes can have diameters of around 8 inches (approximately 20 centimetres) and span the depth of the sea and further, due to the need for slack in the SCR to allow for relative motion between the floating installation and the sea bed installation. All reference herein to flow line diameters refers to the inner diameter of the
15 flow line. Thus a flow line with a given (i.e. inner) diameter D has an internal cross-sectional area of $\pi(D^2)/4$.

The SCRs may hang straight downwards to form a "J"-shape, but it is also common to provide buoyancy in a middle portion of the SCR, to provide, when following along the SCR upwards from the sea bed, a mathematically concave downward shaped
20 portion, followed by a point of inflection and a concave upward shaped portion. The buoyancy is provided by buoyancy aids connected to a supporting sleeve around the middle portion of the SCR. This shape of SCR allows very flexible movement between the subsea and floating installations.

It is desirable to increase the capacity of SCRs to allow increased hydrocarbon
25 flow from the sea bed installation to the floating installation.

According to a first aspect of the invention, there is provided a riser system for transporting hydrocarbons from a sea bed installation towards a floating installation, the riser system comprising a flow path along at least one flow line from the sea bed installation towards the floating installation; wherein the cross sectional area of the flow
30 path is effectively increased towards the floating installation; wherein, in use, hydrocarbons being transported from the sea bed installation can flow towards the floating installation along the flow path.

The present inventors have realised that flow rate through a riser system is limited due to volumetric expansion of the hydrocarbons being transported as they move
35 from the sea bed towards the surface of the sea. This is because a reduction in

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hydrostatic pressure causes an increase in volume of the hydrocarbons, most significantly exhibited by gaseous hydrocarbon components. The hydrocarbons being transported will generally be a hydrocarbon mixture consisting of liquid and gaseous hydrocarbons as well as water and also sometimes contaminants such as sand. The inventors have further realised that the flow-rate limiting portion of the riser system is towards the floating installation, for example in an upper portion, since the increasing volume of the hydrocarbon mixture towards the surface of the sea is restricted by the dimensions of the riser system. Conversely, the flow rate is relatively unhindered at the seabed, where the same molar quantity of hydrocarbon mixture has a much smaller volume, due to the higher hydrostatic pressure.

Consequently, the inventors have realised that the portion of the riser system nearer the sea surface, i.e. towards the floating installation, can be enhanced by increasing the cross sectional area through which the hydrocarbon mixture can flow.

The effective increase in cross sectional area of the flow path may comprise an increase in the diameter of the at least one flow line towards the floating installation, preferably wherein the diameter of the at least one flow line is increased by 2 inches (5 cm), or more.

With this arrangement, the cross sectional area of the riser system can be simply increased within a single main flow line, thereby increasing the volumetric flow rate at the depth below sea level where this was previously restricted by the riser system.

The difference in diameter between the narrower portion and wider portion may be in the range of 0.5 – 5 inches (1.25 – 12.5 cm), preferably in the range of 1 – 4 inches (2.5 – 10 cm), further preferably in the range of 1 – 3 inches (2.5 – 7.5 cm), and further preferably in the range of 1.5– 2.5 inches (3.75 – 6.25 cm).

The at least one flow line may have a narrower portion with a diameter of 8 inches (20 cm) and a wider portion with a diameter of 10 inches (25 cm). The at least one flow line may have a narrower portion with a diameter of 9 inches (22.5 cm) and a wider portion with a diameter of 11 inches (27.5 cm). The at least one flow line may have a narrower portion with a diameter of 10 inches (25 cm) and a wider portion with a diameter of 12 inches (30 cm). The wider portion is the portion of the flow line towards the floating installation and the narrower portion is the portion of the flow line towards the sea bed installation.

The at least one flow line may comprise insulation around its wider portion (the portion having the larger diameter) and may comprise less or no insulation around its wider portion (the portion having the larger diameter).

Additionally or alternatively, the effective increase in cross sectional area of the flow path may include the use of multiple parallel flow lines, with a main flow line and at least one further flow line providing parallel flow paths to increase the cross-sectional area of the total flow path towards the floating installation, preferably wherein at least one further flow line comprises at least one flexible flow line having an upper end for communication with the floating installation and a lower end fluidly connected to the main flow line, for example at a mid-point of the main flow line. The at least one flexible flow line may comprise a plurality of flexible flow lines.

This arrangement allows the hydrocarbon mixture to flow in multiple paths in a parallel manner towards the floating installation, thereby increasing the volumetric flow rate at the depth below sea level where this was previously restricted by the riser system. Thus, the hydrocarbons being transported may first flow from the sea bed installation, through the main flow line of the flow path of the riser system, and then the flow may be split into parallel flows that proceed to the floating installation through the at least one flexible flow line and also through the main flow line.

The flow may split at a point where the expansion of hydrocarbons as they flow toward the floating installation might otherwise restrict the flow rate. This can be a mid-point of the main flow line as mentioned above, for example a point within the central 50% of the vertical extent of the main flow line.

Further, if the at least one flexible flow line comprises a plurality of flexible flow lines, then several streams of parallel flow can be provided, thereby providing a greater effective cross-sectional area of flow path for the hydrocarbons. The riser system may have a main flow line with an increase in diameter as well as at least one additional flow line as discussed above.

The at least one flow line (main flow line) may comprise a Steel Catenary Riser, SCR, comprising: a lower portion having a lower end for receiving hydrocarbons from a sea bed installation, a middle portion configured to be supported by at least one buoyancy aid, and an upper portion having an upper end for fluid communication with the floating installation.

The middle portion of the SCR is located between the lower portion of the SCR and the upper portion of the SCR in relation to the flow of hydrocarbons between the sea bed installation and the floating installation. The flexible flow line and main flow line or SCR may be formed with a steel construction, such as a conventionally known steel construction as used for prior art risers and the like.

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The increase in diameter of the at least one flow line (main flow line) may be located at the upper portion of the SCR and preferably also at the middle portion of the SCR.

With this arrangement, the effective cross sectional area of the riser can be increased, at the depth below sea level where this was previously restricted by the riser system, thereby increasing the volumetric flow rate.

The middle portion of the SCR may comprise at least one connector for fluid connection of the SCR to a lower end of the at least one flexible flow line; wherein, in use, hydrocarbons being transported from the sea bed installation can flow towards the floating installation through the upper portion of the SCR and through the at least one flexible flow line.

This arrangement allows the hydrocarbon mixture to flow in multiple paths in a parallel manner through the upper portion of the SCR as well as through the at least one flexible flow line, thereby increasing the volumetric flow rate at the depth below sea level where this was previously restricted by the SCR. Thus, the hydrocarbons being transported may first flow through the lower portion of the SCR to the middle portion, and then the flow may be split into parallel flows that proceed to the floating installation through the at least one flexible flow line and also through the upper portion of the SCR.

The at least one connector may be a T-connector or a functionally equivalent connector for providing a branched connection with flow tapped off from the main flow path at the middle portion of the SCR. The connector may provide a fluid connection for a single flexible flow line. In the case of a plurality of flexible flow lines then a single connector may provide a flow that supplies fluid to multiple flexible flow lines, or there may be multiple connectors each providing flow to one or more than one of the plurality of flexible flow lines.

The riser system may further comprise at least one valve for controlling fluid flow through the at least one flexible flow line. The valve may be integrated with the connector. Where there are a plurality of flexible flow lines then multiple valves may be provided, for example one valve for controlling fluid flow through each of the flow lines. In this arrangement, selective use can be made of the flexible flow lines. For example, all of the flexible flow lines can be shut off with valves to direct all hydrocarbon flow via the SCR. Alternatively, the flow rate of the hydrocarbons can be adjusted by selectively opening or closing one or more valves, to increase or reduce the effective cross sectional area for the flow path of the hydrocarbons towards the surface of the sea.

The riser system may include the at least one buoyancy aid for supporting the middle portion of the SCR. This buoyancy aid may have a similar construction to known buoyancy aids used with SCRs and similar structures.

The riser system may further comprise at least one buoyancy aid for supporting the at least one flexible flow line. In this manner, the floating installation does not have to fully support the excess weight of the flexible flow line, which can instead be supported by the at least one buoyancy aid. Additionally, buoyancy aids can help reduce forces on the connector between the at least one flexible flow line and the SCR.

The diameter of the at least one flexible flow line may be between 10% and 90% of that of the SCR. It may be between 10% and 50%. It may be between 10% and 30%. It may be between 10% and 20% of that of the SCR.

The diameter of the at least one flexible flow line may be in the range of 6-8 inches (15-20 cm) and the diameter of the SCR may be in the range of 8-12 inches (20-30 cm).

Since the at least one flexible flow line has a much smaller diameter than the SCR, it will not add significant quantities of weight compared to a flexible flow line having substantially the same diameter as the SCR.

There may be multiple flexible flow lines having any of the above relative diameters compared to the SCR and controllable by at least one valve. This arrangement allows good control over the effective flow cross-sectional area for the hydrocarbons, since closing or opening a valve will decrease or increase the effective cross sectional area incrementally, allowing improved control.

The floating installation may be an installation floating at the sea surface, such as a floating platform or a floating production, storage and offloading vessel (FPSO) or a Floating Storage and Offloading vessel (FSO). Alternatively, the floating installation may be located beneath the sea surface, for example it may be arranged for onward connection to a vessel such as FSO or FPSO that might be temporarily connected to the submerged floating installation. The riser system may further comprise a manifold for connection of the upper end of the upper portion of the SCR and the upper end of the flexible flow line. Such a manifold may be located at the floating installation. With this arrangement, the parallel flow can be combined at or near the surface of the sea for piping off to storage tankers and the like.

The lower end of the SCR may be arranged to receive hydrocarbons directly from a sea bed installation, or there may be further flow lines between the lower end of the SCR and a source of hydrocarbons at some remote location.

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According to a second aspect of the invention, there is provided a method for transporting hydrocarbons from a sea bed installation towards a floating installation, comprising: providing a riser system comprising a flow path along at least one flow line from the sea bed installation towards the floating installation; effectively increasing the flow path cross sectional area towards the floating installation; and transporting hydrocarbons from the sea bed installation towards the floating installation along the flow path.

As described above, the inventors have realised that the portion of the riser system nearer the floating installation, can be enhanced by increasing the cross sectional area of the flow path through which the hydrocarbon mixture can flow.

The step of effectively increasing the flow path cross sectional area may comprise: increasing the diameter of the at least one flow line towards the floating installation, preferably increasing the diameter by 2 inches (5 cm) or more.

With this method, the cross sectional area of the riser system can be simply increased within a single main flow line, thereby increasing the volumetric flow rate at the depth below sea level where this was previously restricted by the riser system.

The difference in diameter between the narrower portion and wider portion may be in the range of 0.5 – 5 inches (1.25 – 12.5 cm), preferably in the range of 1 – 4 inches (2.5 – 10 cm), further preferably in the range of 1 – 3 inches (2.5 – 7.5 cm), and further preferably in the range of 1.5– 2.5 inches (3.75 – 6.25 cm).

The at least one flow line may have a narrower portion with a diameter of 8 inches (20 cm) and a wider portion with a diameter of 10 inches (25 cm). The at least one flow line may have a narrower portion with a diameter of 9 inches (22.5 cm) and a wider portion with a diameter of 11 inches (27.5 cm). The at least one flow line may have a narrower portion with a diameter of 10 inches (25 cm) and a wider portion with a diameter of 12 inches (30 cm). The wider portion is the portion of the flow line towards the floating installation and the narrower portion is the portion of the flow line towards the sea bed installation.

The at least one flow line may comprise insulation around its wider portion (the portion having the larger diameter) and may comprise less or no insulation around its wider portion (the portion having the larger diameter).

Additionally or alternatively, the step of effectively increasing the flow path cross sectional area may include using multiple parallel flow lines with a main flow line and at least one further flow line providing parallel flow paths to increase the cross-sectional area of the total flow path towards the floating installation, preferably wherein at least

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one further flow line comprises at least one flexible flow line having an upper end for communication with the floating installation and a lower end fluidly connected to the main flow line, for example at a mid-point of the main flow line. The at least one flexible flow line may comprise a plurality of flexible flow lines.

5 This method allows the hydrocarbon mixture to flow in multiple paths in a parallel manner towards the floating installation, thereby increasing the volumetric flow rate at the depth below sea level where this was previously restricted by the riser system.

Thus, the hydrocarbons being transported may first flow from the sea bed installation, through the main flow line of the flow path of the riser system, and then the flow may be
10 split into parallel flows that proceed to the floating installation through the at least one flexible flow line and also through the main flow line.

The flow may split at a point where the expansion of hydrocarbons as they flow toward the floating installation might otherwise restrict the flow rate. This can be a mid-point of the main flow line as mentioned above, for example a point within the central
15 50% of the vertical extent of the main flow line.

Further, if the at least one flexible flow line comprises a plurality of flexible flow lines, then several streams of parallel flow can be provided, thereby providing a greater effective cross-sectional area of flow path for the hydrocarbons. The riser system may have a main flow line with an increase in diameter as well as at least one additional flow
20 line as discussed above.

The at least one flow line (main flow line) may comprise a Steel Catenary Riser, SCR, comprising: a lower portion having a lower end for receiving hydrocarbons from a sea bed installation, a middle portion configured to be supported by at least one buoyancy aid, and an upper portion having an upper end for fluid communication with
25 the floating installation.

The middle portion of the SCR is located between the lower portion of the SCR and the upper portion of the SCR in relation to the flow of hydrocarbons between the sea bed installation and the floating installation.

The flexible flow line and main flow line or SCR may be formed with a steel
30 construction, such as a conventionally known steel construction as used for prior art risers and the like.

The step of increasing the diameter of the at least one flow line (main flow line) may be carried out at the upper portion of the SCR and preferably also at the middle portion of the SCR.

With this method, the effective cross sectional area of the riser can be increased, at the depth below sea level where this was previously restricted by the riser system, thereby increasing the volumetric flow rate.

The method may comprise providing the middle portion of the SCR with at least one connector for fluid communication with the at least one flexible flow line; and fluidly connecting the middle portion of the SCR to a lower end of the at least one flexible flow line; wherein the step of transporting hydrocarbons comprises transporting hydrocarbons from the sea bed installation towards the floating installation through the upper portion of the SCR and through the at least one flexible flow line.

This method allows the hydrocarbon mixture to flow in multiple paths in a parallel manner through the upper portion of the SCR as well as through the at least one flexible flow line, thereby increasing the volumetric flow rate at the depth below sea level where this was previously restricted by the SCR. Thus, the hydrocarbons being transported may first flow through the lower portion of the SCR to the middle portion, and then the flow may be split into parallel flows that proceed to the floating installation through the at least one flexible flow line and also through the upper portion of the SCR.

The at least one connector may be a T-connector or a functionally equivalent connector for providing a branched connection with flow tapped off from the main flow path at the middle portion of the SCR. The connector may provide a fluid connection for a single flexible flow line. In the case of a plurality of flexible flow lines then a single connector may provide a flow that supplies fluid to multiple flexible flow lines, or there may be multiple connectors each providing flow to one or more than one of the plurality of flexible flow lines.

The method may comprise the steps of providing at least one valve; and controlling fluid flow through the at least one flexible flow line using the at least one valve. The valve may be integrated with the connector. Where there are a plurality of flexible flow lines then multiple valves may be provided, for example one valve for controlling fluid flow through each of the flow lines.

With this method, selective use can be made of the flexible flow lines. For example, all of the flexible flow lines can be shut off with valves to direct all hydrocarbon flow via the SCR. Alternatively, the flow rate of the hydrocarbons can be adjusted by selectively opening or closing one or more valves, to increase or reduce the effective cross sectional area for the flow path of the hydrocarbons towards the surface of the sea.

The method may include providing the buoyancy aid for supporting the middle portion of the SCR. This buoyancy aid may have a similar construction to known buoyancy aids used with SCRs and similar structures.

5 The method may comprise the steps of providing at least one buoyancy aid for the at least one flexible flow line; and supporting the at least one flexible flow line using the at least one buoyancy aid.

10 With this method, the floating installation does not have to fully support the excess weight of the at least one flexible flow line, which can instead be supported by the at least one buoyancy aid. Additionally, buoyancy aids can help reduce forces on the connector between the at least one flexible flow line and the SCR.

The diameter of the at least one flexible flow line may be between 10% and 90% of that of the SCR, preferably between 10% and 50%, further preferably between 10% and 30% and even further preferably between 10% and 20% of that of the SCR.

15 The diameter of the at least one flexible flow line may be in the range of 6-8 inches (15-20 cm) and the diameter of the SCR may be in the range of 8-12 inches (20-30 cm).

Since the at least one flexible flow line has a much smaller diameter than the SCR, it will not add significant quantities of weight compared to a flexible flow line having substantially the same diameter as the SCR.

20 There may be provided multiple flexible flow lines having any of the above relative diameters compared to the SCR and controllable by at least one valve. This arrangement allows good control over the effective flow cross-sectional area for the hydrocarbons, since closing or opening a valve will decrease or increase the effective cross sectional area incrementally, allowing improved control.

25 The floating installation may be an installation floating at the sea surface, such as a floating platform or a floating production, storage and offloading vessel (FPSO) or a Floating Storage and Offloading vessel (FSO). Alternatively, the floating installation may be located beneath the sea surface, for example it may be arranged for onward connection to a vessel such as FSO or FPSO that might be temporarily connected to the submerged floating installation.

30 The method may comprise providing a manifold; and connecting the upper end of the upper portion of the SCR and the upper end of the flexible flow line to the manifold. With this method, the parallel flow can be combined at or near the surface of the sea for piping off to storage tankers and the like.

The lower end of the SCR may be arranged to receive hydrocarbons directly from a sea bed installation, or there may be further flow lines between the lower end of the SCR and a source of hydrocarbons at some remote location.

Further embodiments of the present invention will now be described by way of example only and with reference to the drawings in which:

Figure 1 shows schematically a conventional SCR; and

Figure 2 shows schematically an apparatus comprising an SCR and multiple flexible flow lines.

In offshore hydrocarbon extraction, the distance from the sea bed to the sea level can often be in the order of several kilometres, such as 3 kilometres. Since hydrostatic pressure increases with distance below the sea surface, the hydrostatic pressure at the sea bed will be much greater than near to the surface of the sea. Thus, as shown in Figure 2, the pressure near the surface of the sea can be in the region of about 470 bar (gauge pressure), while it can be as high as 690 bar (gauge pressure) near the sea bed about 9600 ft (2.9 km) below the sea surface.

The hydrocarbons transported to the surface generally contain a mixture of oil and gas and may contain other constituents. Since gases are significantly compressible (compared to liquids), then the volume per unit weight of the mixture at the sea bed (at high hydrostatic pressure) will be much smaller than the volume per unit weight at the surface of the sea (at negligible hydrostatic pressure). To illustrate this further, assuming the ideal gas equation for the gaseous portion of the hydrocarbon mixture:

$$pV=nRT$$

where p is pressure, V is volume, n is the number of moles, R is the gas constant and T is the temperature, then it is clear that for a fixed quantity (moles) of gas, the volume of the gas V is proportional to T/p . Although temperature varies with depth, generally reducing with depth, it is clear that the volume of the gas V is inversely proportional to the pressure p . Thus at the sea bed, a fixed molar quantity of gas has a relatively high pressure p and a relatively small volume V compared to the same molar quantity of gas near the surface of the sea, which has a relatively low pressure p and a relatively large volume V . Thus it can be seen that the hydrocarbon mixture will expand in volume as it passes up the SCR towards the surface of the sea.

The result of this volumetric expansion is a restriction of flow rate within the SCR as the hydrocarbon mixture approaches the surface of the sea. Conventional SCRs can have diameters of up to 8 inches (approximately 20 centimetres) and have a length that is sufficient to span the depth of the sea and further, due to the need for slack in the

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SCR to allow for relative motion between a floating installation and the sea bed installation. This leads to a very heavy SCR which also must be strong enough to support its own weight, as well as the hydrocarbons passing through it.

Larger diameter SCRs could be used to provide increased flow rates. However, increasing the diameter of the SCR significantly beyond the conventional 8 inch (approximately 20 centimetre) SCRs leads to significant increased weight of the SCR and will necessitate a significant increase in strength of the SCR. Since increased strength is associated with increased material thickness of the SCR wall structure, this in turn will add even more weight to the SCR. Thus, it is advantageous to maximise the utility of any given diameter of SCR, whether this is the widely used 8 inch size, or larger sizes.

Figure 1 shows a conventional SCR 100, with one end being a hangoff location 102 near the sea surface for connection to a floating installation and the other end being a touchdown point 104 for connection to the sea bed. The SCR 100 comprises three consecutive portions, namely, a hangoff catenary portion 110, a buoyancy catenary portion 120 and a touchdown catenary portion 130. The hangoff catenary portion 110 forms an upper portion 110 of the SCR 100, the buoyancy catenary portion 120 forms a middle portion 120 of the SCR 100, and the touchdown catenary portion 130 forms a lower portion 130 of the SCR 100.

As its name suggests, the hangoff catenary portion 110 comprises the portion of the SCR 100 extending from the hangoff location 102. The hangoff catenary portion comprises (from the hangoff location 102) a hanging section 112, followed by a sag bend 114 and subsequently a jumper section 116. Connected to the end of jumper 116 is a lift point 122 of the buoyancy catenary portion 120.

The buoyancy catenary portion 120 extends from the lift point 122 to a drag point 129 and comprises a lift section 124, an arch section 126 and a drag section 128 in that order. The touchdown catenary portion 130 extends from the drag point 129 to the touchdown point 104 of the SCR 100 on the sea bed.

As can be seen, the SCR 100 forms a downward catenary shape due to the self-weight of the SCR 100 in each of the hangoff and touchdown catenary portions 110, 130, and an upward catenary shape due to the buoyancy of the SCR 100 in the buoyancy catenary portion 120.

It can also be seen from Figure 1 that the arch bend 126 of the buoyancy catenary portion 120 is located at about 2000 ft (about 600 m) above the sea bed.

Figure 2 shows an apparatus comprising the SCR 100 of Figure 1 and flexible flow lines 200. For clarity, some reference signs are not shown; however it should be understood that SCR 100 is the same in both Figures.

As shown in Figure 2, the flexible flow lines 200 are connected to the SCR 100 at the buoyancy catenary portion 120 of the SCR 100. The flexible flow lines comprise conventional flexible hydrocarbon lines having a diameter smaller than or equal to that of the SCR 100. For example, if the SCR 100 has a diameter of 8 to 12 inches (about 20 to 30 cm), the flexible flow line may have a diameter of 2 to 8 inches (about 5 to 20 cm).

There are connectors 210 between the flexible flow lines 200 and the buoyancy catenary portion 120 of the SCR 100. The connectors 210 may be T-shaped.

The weight of the flexible flow lines 200 may be supported by a buoyancy aid 220, which ensures that the catenary shape of the SCR 200 is not lost under the weight of the flexible flow lines 200.

The flexible flow lines 200 may meet at the surface of the sea near the hangoff location 102 of the SCR 100, at a manifold 300.

In use, hydrocarbons comprising liquid and gas are piped from a sea bed hydrocarbon installation, via the SCR 100 toward the surface of the sea at which there is a floating installation, such as a floating platform, FPSO or FSO. All of the piped hydrocarbons pass through the touchdown portion 130 of the SCR 100. As the hydrocarbons pass along the buoyancy catenary portion 120 of the SCR, some of the hydrocarbon fluid is directed away from the SCR 100, via the flexible flow lines 200 towards the floating installation. The reminder of the hydrocarbon fluid continues through the SCR 100, along the buoyancy catenary portion 120 and through the hangoff catenary portion 110 towards the floating installation. Thus there are several parallel flows of hydrocarbon fluid towards the hydrocarbon sea surface installation. This ensures that the rate of flow of the hydrocarbon is not limited by the diameter of the flow lines as the hydrocarbon fluid expands volumetrically under conditions of reducing pressure as the hydrocarbon fluid moves towards the surface of the sea.

Put another way, as the hydrocarbon fluid expands volumetrically, in order to achieve a constant, unrestricted flow rate towards the surface of the sea, it will need to flow through an increased cross-sectional area. By adding the flexible flow lines 200 to the SCR 100, there is a greater cross-sectional area through which the fluid can flow, which can be envisaged as a greater "effective diameter" of the SCR 100.

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Each of the flexible flow lines 200 has a valve 400 which can be controlled by a controller 500, to regulate the flow rate of the hydrocarbon fluid by altering the “effective diameter” of the SCR 100.

5 The skilled person will understand that the above description refers to preferred embodiments of the invention only, and other alternatives may be included within the invention, the scope of which is defined in the claims.

For example, the SCR 100 may have a diameter of 8 inches (20 cm), 10 inches (25 cm) or 12 inches (30 cm) for example. There may be one or more flexible flow lines 200.

10 Each flow line may have a valve 400, or may not have a valve 400. Alternatively, there may be one valve 400 for controlling the flow in all of the flow lines 200.

Additionally or alternatively, the SCR 100 may have a smaller first diameter in the lower portion 130 and a second larger diameter in the upper portion 110. The middle portion 120 may have the larger diameter, the smaller diameter or may comprise a mixture of the two diameters. This creates an effective means for increasing the cross sectional area of the flow path from the sea bed installation to the floating installation, thereby mitigating the effect of the diameter of the SCR 100 in restricting the flow of the hydrocarbons towards to surface installation.

20 The same increases in cross-sectional area, using an increase in diameter and/or the addition of flexible flow lines in parallel with the riser, can be used with other riser configurations. For example, a “J” shape riser”.

CLAIMS

1. A riser system for transporting hydrocarbons from a sea bed installation towards a floating installation, the riser system comprising a flow path along at least one flow line from the sea bed installation towards the floating installation;

wherein the cross sectional area of the flow path is effectively increased towards the floating installation;

wherein, in use, hydrocarbons being transported from the sea bed installation can flow towards the floating installation along the flow path.

2. A riser system as claimed in claim 1, wherein the effective increase in cross sectional area of the flow path comprises:

an increase in the diameter of the at least one flow line towards the floating installation, preferably wherein the diameter of the at least one flow line is increased by 2 inches (5 cm) or more; and/or

the use of multiple parallel flow lines, with a main flow line and at least one further flow line providing parallel flow paths to increase the cross-sectional area of the total flow path towards the floating installation, preferably wherein the at least one further flow line comprises at least one flexible flow line having an upper end for communication with the floating installation and a lower end fluidly connected to the main flow line, further preferably wherein the at least one flexible flow line comprises a plurality of flexible flow lines.

3. A riser system as claimed in claim 1 or 2, wherein the at least one flow line comprises a Steel Catenary Riser, SCR, comprising: a lower portion having a lower end for receiving hydrocarbons from a sea bed installation, a middle portion configured to be supported by at least one buoyancy aid, and an upper portion having an upper end for fluid communication with the floating installation.

4. A riser system as claimed in claim 3, wherein the increase in diameter of the at least one flow line is located at the upper portion of the SCR and preferably also at the middle portion of the SCR.

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5. A riser system as claimed in claim 3 or 4, wherein the middle portion of the SCR comprises at least one connector for fluid connection of the SCR to a lower end of the at least one flexible flow line;

wherein, in use, hydrocarbons being transported from the sea bed installation can flow towards the floating installation through the upper portion of the SCR and through the at least one flexible flow line.

6. A riser system as claimed in claim 5, wherein the at least one connector is a T-connector or a functionally equivalent connector for providing a branched connection with flow tapped off from the main flow path at the middle portion of the SCR.

7. A riser system as claimed in claim 5 or 6, further comprising at least one valve for controlling fluid flow through the at least one flexible flow line; preferably wherein the valve is integrated with the connector.

8. A riser system as claimed in any of claims 3 to 7, further comprising at least one buoyancy aid for supporting the at least one flexible flow line.

9. A riser system as claimed in any of claims 3 to 8, wherein the diameter of the SCR is in the range of 8-12 inches (20-30 cm) and the diameter of the at least one flexible flow line is in the range of 6-8 inches (15-20 cm).

10. A riser system as claimed in any of claims 3 to 9, further comprising a manifold for connection of the upper end of the upper portion of the SCR and the upper end of the flexible flow line; preferably wherein the manifold is located at the floating installation.

11. A method for transporting hydrocarbons from a sea bed installation towards a floating installation, comprising:

providing a riser system comprising a flow path along at least one flow line from the sea bed installation towards the floating installation;

effectively increasing the flow path cross sectional area towards the floating installation; and

transporting hydrocarbons from the sea bed installation towards the floating installation along the flow path.

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12. A method as claimed in claim 11, wherein effectively increasing the flow path cross sectional area comprises:

increasing the diameter of the at least one flow line towards the floating
5 installation, preferably increasing the diameter by 2 inches (5 cm) or more; and/or
using multiple parallel flow lines with a main flow line and at least one further flow line providing parallel flow paths to increase the cross-sectional area of the total flow path towards the floating installation, preferably wherein the at least one further flow line comprises at least one flexible flow line having an upper end for communication with the
10 floating installation and a lower end fluidly connected to the main flow line, further preferably wherein the at least one flexible flow line comprises a plurality of flexible flow lines.

13. A method as claimed in claim 11 or 12, wherein the at least one flow line
15 comprises a Steel Catenary Riser, SCR, comprising: a lower portion having a lower end for receiving hydrocarbons from a sea bed installation, a middle portion configured to be supported by at least one buoyancy aid, and an upper portion having an upper end for fluid communication with the floating installation.

14. A method as claimed in claim 13, wherein increasing the diameter of the at least
20 one flow line is carried out at the upper portion of the SCR and preferably also at the middle portion of the SCR.

15. A method as claimed in claim 13 or 14, further comprising:

25 providing the middle portion of the SCR with at least one connector for fluid communication with the at least one flexible flow line; and

fluidly connecting the middle portion of the SCR to a lower end of the at least one flexible flow line; and

wherein the step of transporting hydrocarbons comprises transporting
30 hydrocarbons from the sea bed installation towards the floating installation through the upper portion of the SCR and through the at least one flexible flow line.

16. A method as claimed in claim 15, wherein the at least one connector is a T-
connector or a functionally equivalent connector for providing a branched connection
35 with flow tapped off from the main flow path at the middle portion of the SCR.

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17. A method as claimed in claim 15 or 16, further comprising: providing at least one valve; and

5 controlling fluid flow through the at least one flexible flow line using the at least one valve;

preferably wherein the valve is integrated with the connector.

18. A method as claimed in any of claims 13 to 17, further comprising:

10 providing at least one buoyancy aid for the at least one flexible flow line; and supporting the at least one flexible flow line using the at least one buoyancy aid.

19. A method as claimed in any of claims 13 to 18, wherein the diameter of the SCR is in the range of 8-12 inches (20-30 cm) and the diameter of the at least one flexible flow line is in the range of 6-8 inches (15-20 cm).

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20. A method as claimed in any of claims 13 to 19, further comprising:

providing a manifold; and

connecting the upper end of the upper portion of the SCR and the upper end of the flexible flow line to the manifold;

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preferably wherein the manifold is located at the floating installation.

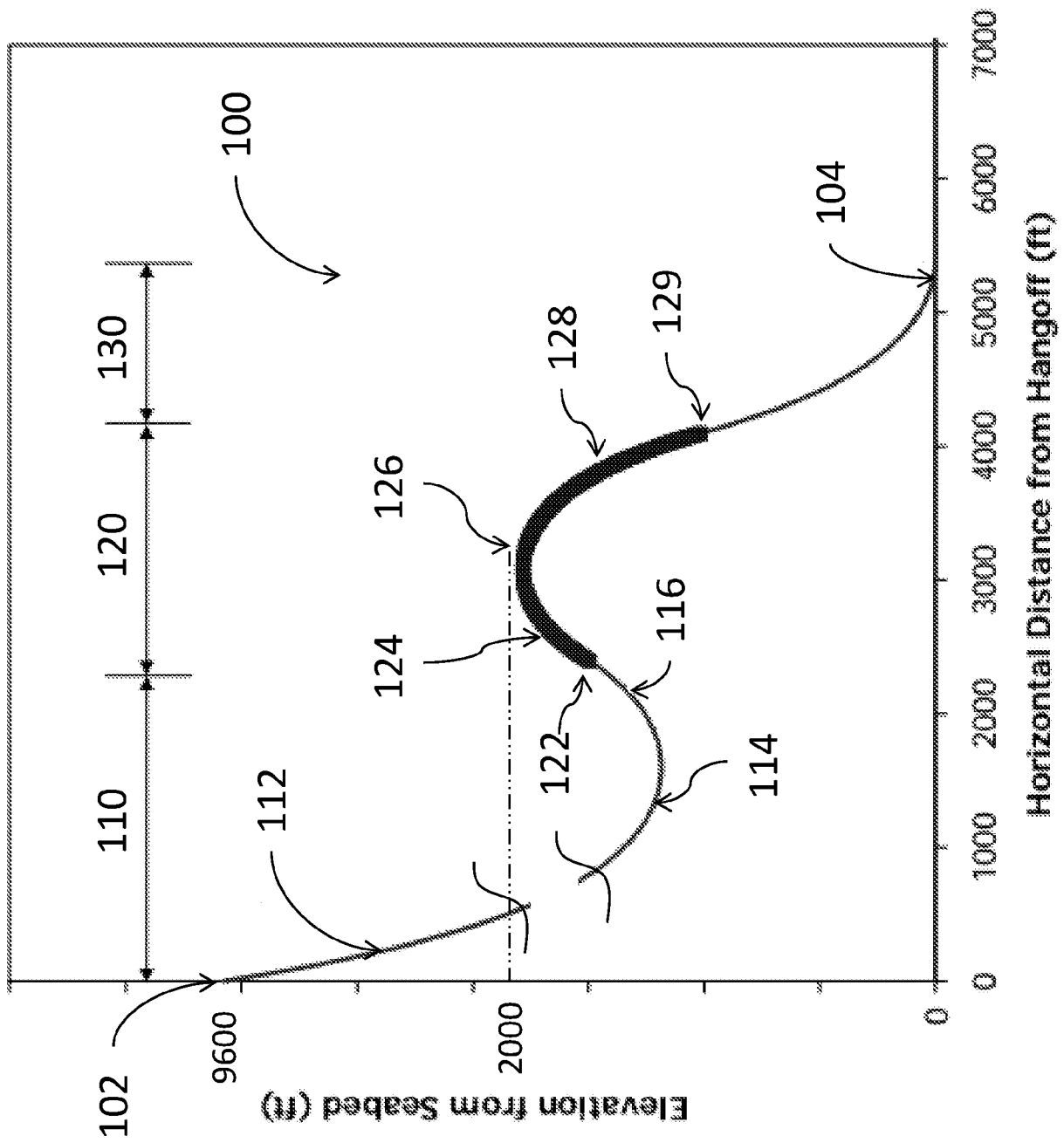


Figure 1 - Prior Art

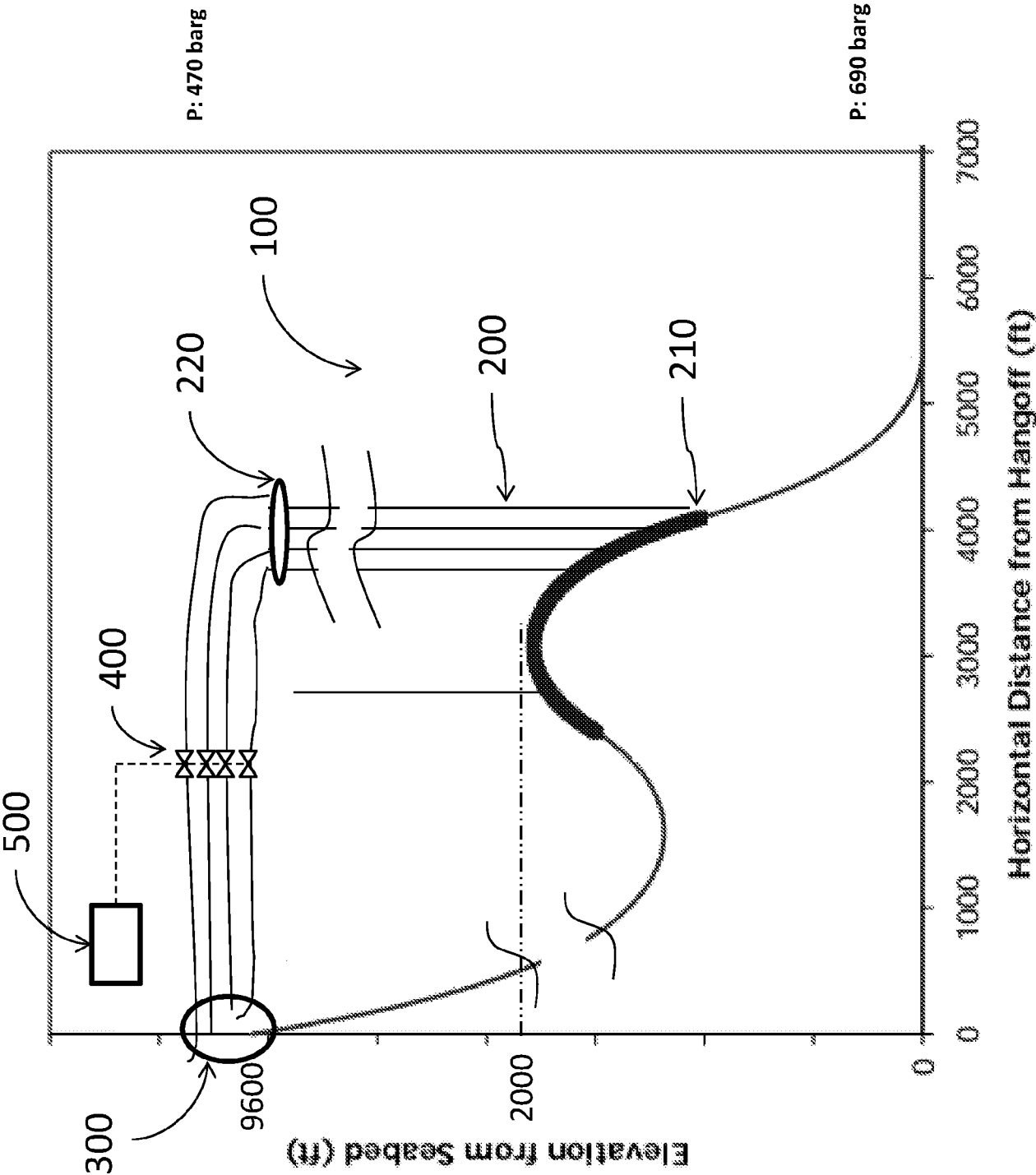


Figure 2

INTERNATIONAL SEARCH REPORT

International application No.

PCT/NO2018/050002

A. CLASSIFICATION OF SUBJECT MATTER E21B 17/01 (2006.01), E21B 17/02 (2006.01), E21B 43/01 (2006.01) 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: E21B Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched DK, NO, SE, FI: Classes as above. Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPODOC, WPI, FULL TEXT: ENGLISH		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011/0127029 A1 (GANELIN, B. ET AL.) 2011.06.02 Paragraphs [0012]-[0014], [0058]-[0060] and [0061]-[0066]; figures 12-16	1-4, 8-14, 18-20
A		5-7, 15-17
A	GB 2380747 A (ROCKWATER LTD.) 2003.04.16 Page 14 lines 11-25, page 18 lines 4-12; figures 8, 9 and 15	1-20
A	GB 2090221 A (MOBIL OIL CORP.) 1982.07.07 Abstract; page 3 lines 98-121; figure 1	1-20
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents: “A” document defining the general state of the art which is not considered to be of particular relevance “E” earlier application or patent but published on or after the international filing date “L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) “O” document referring to an oral disclosure, use, exhibition or other means “P” document published prior to the international filing date but later than the priority date claimed “T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention “X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone “Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art “&” document member of the same patent family		
Date of the actual completion of the international search		Date of mailing of the international search report
16/03/2018		19/03/2018
Name and mailing address of the ISA Nordic Patent Institute Helgeshøj Allé 81 DK - 2630 Taastrup, Denmark. Facsimile No. + 45 43 50 80 08		Authorized officer Westbye, Daniel Telephone No. +47 22 38 74 32

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/NO2018/050002

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