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(54) SYSTEM FOR ACCOMMODATING MOTION OF A FLOATING BODY

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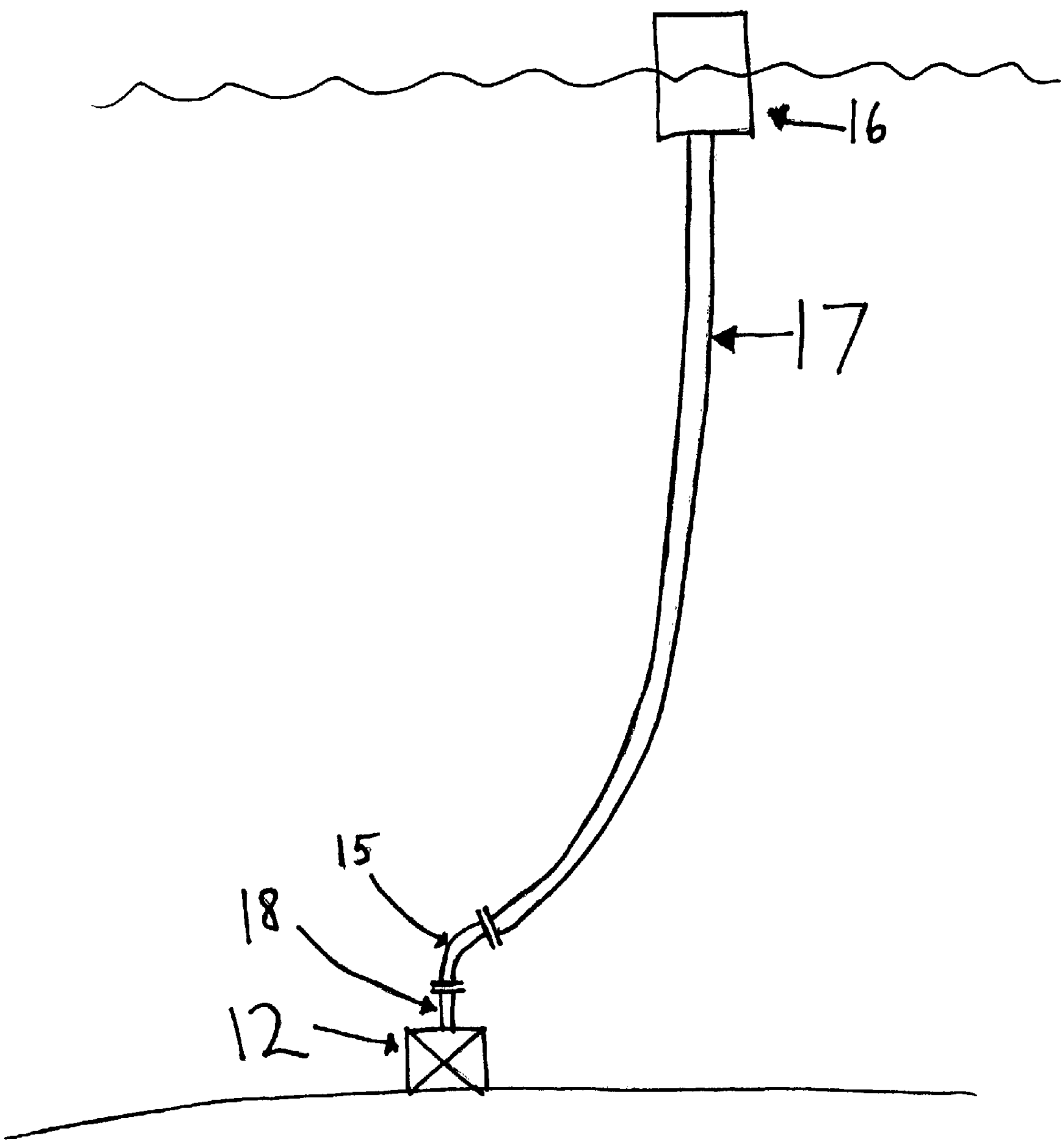
(57) ABSTRACT

A system is provided for compensation for motion of a floating platform connected to a riser having at least two segments connected by an elbow. According to various example embodiments, a pre-determined portion of the riser flex in response to heave of the platform. In various example embodiments, the pre-determined portion comprises pre-formed curves that flex in response to the heave of the platform.



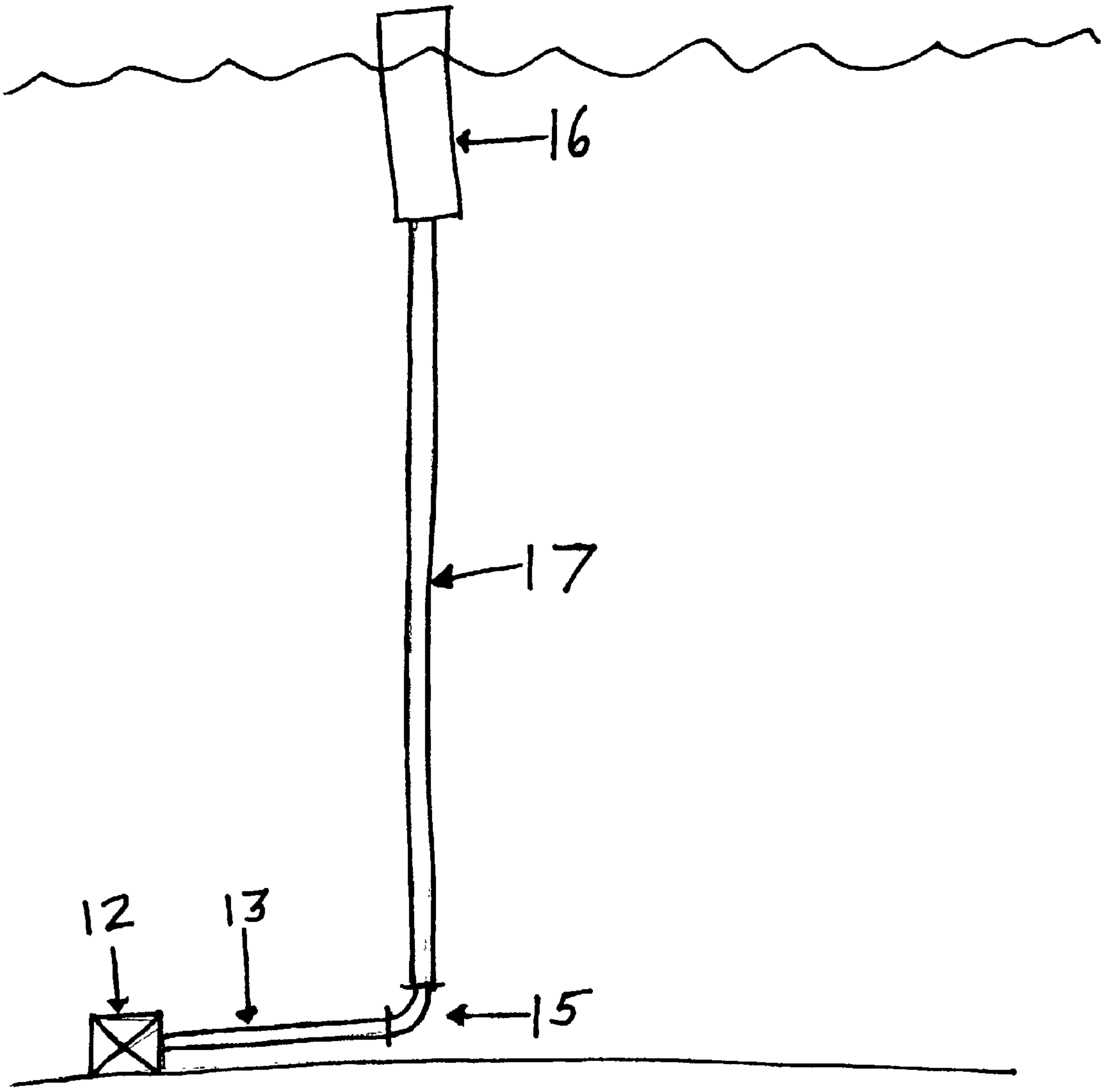


Figure 1

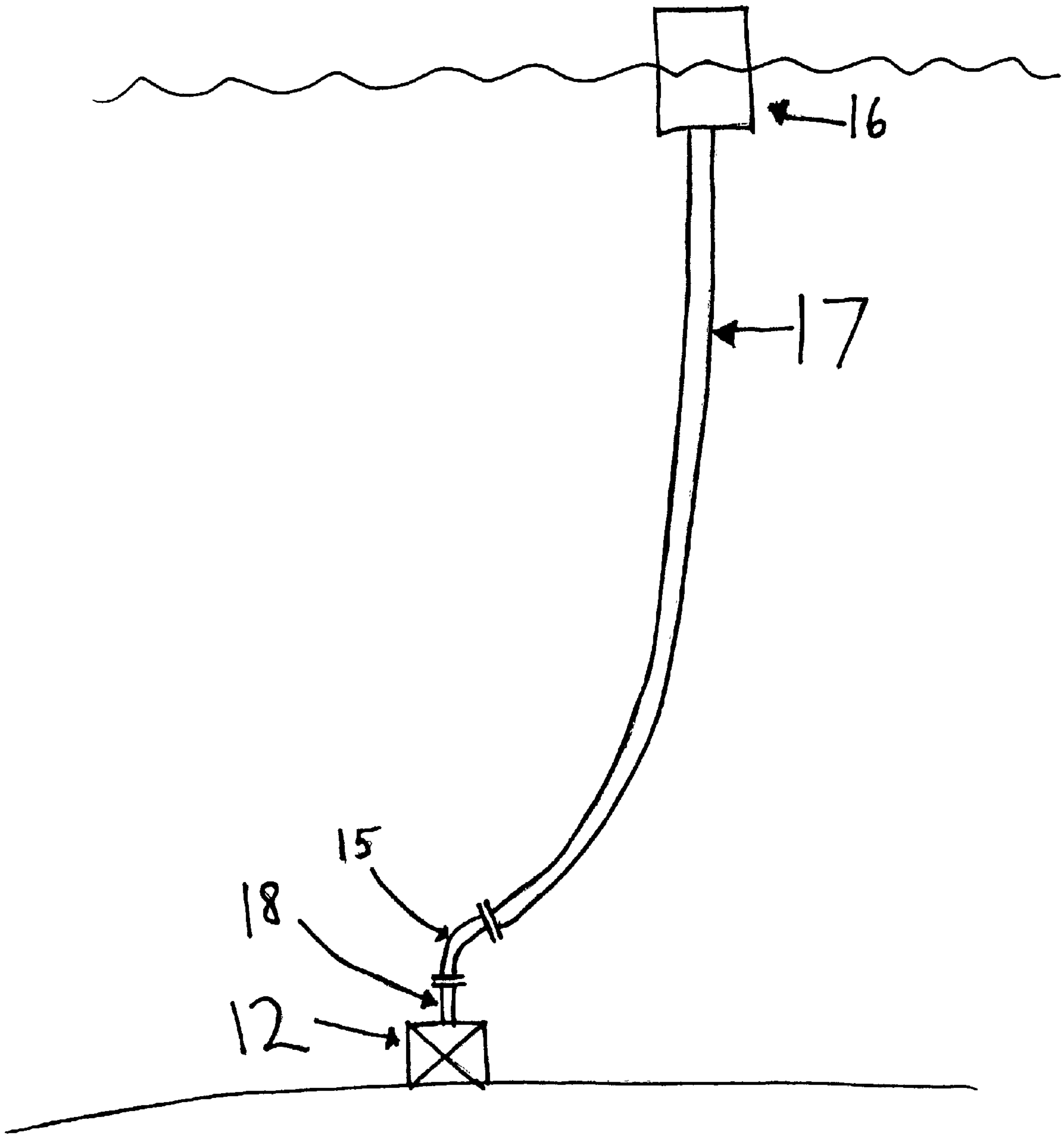


Figure 2

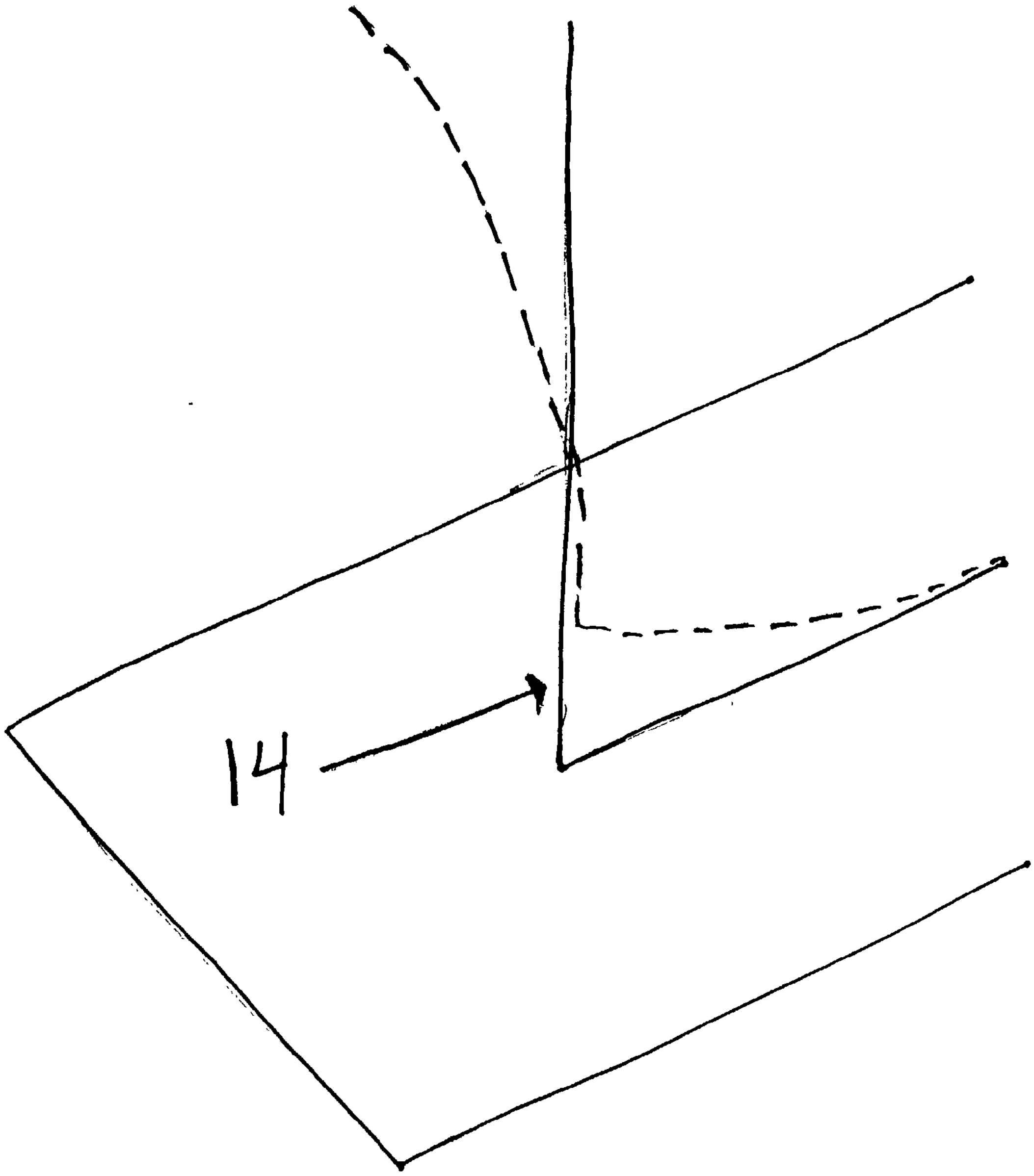


Figure 3

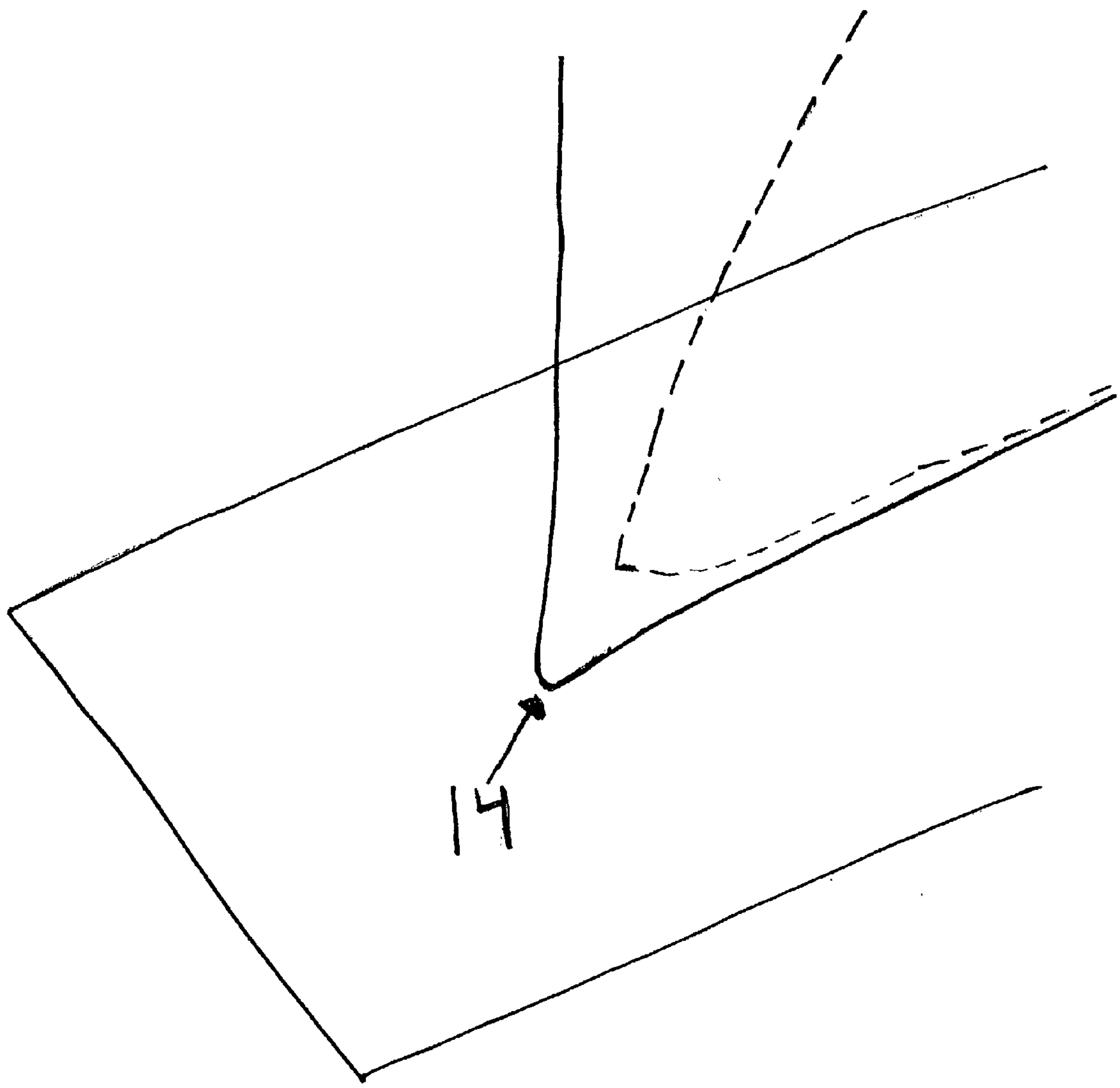


Figure 4

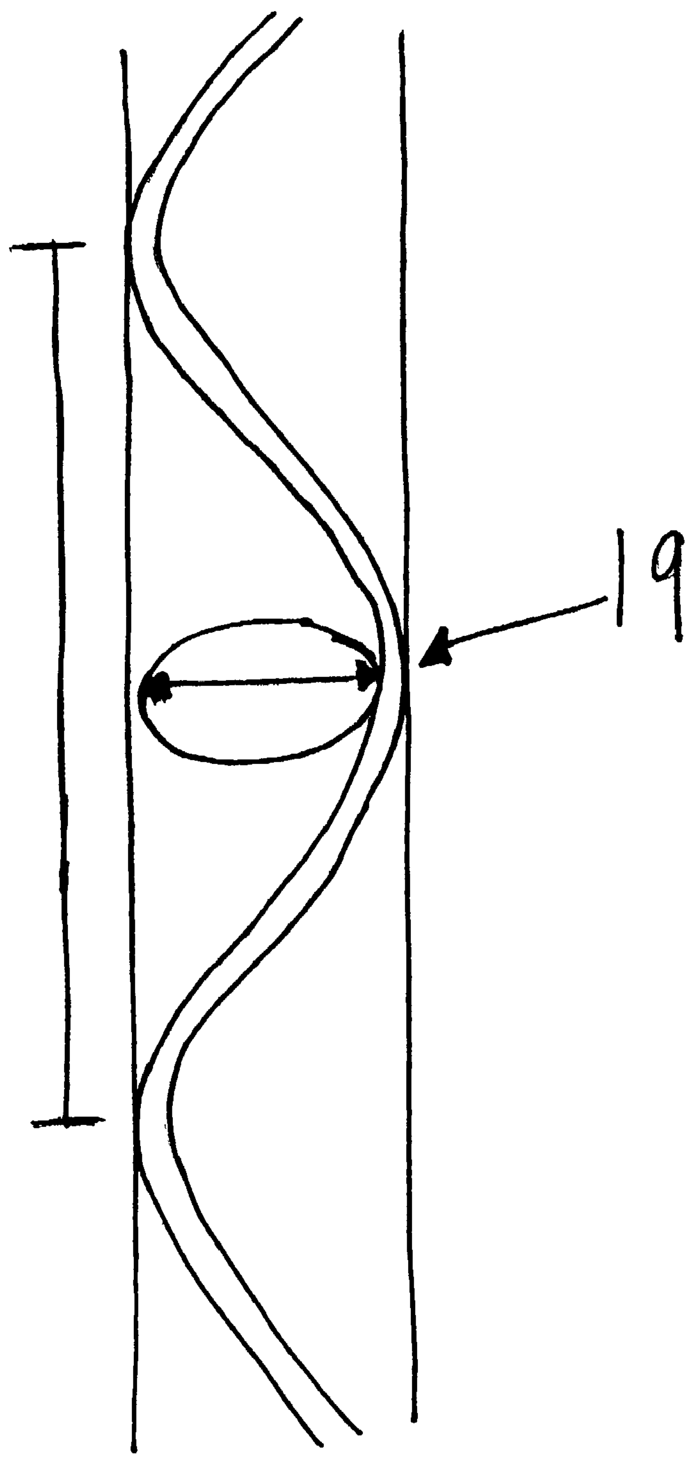


Figure 5A

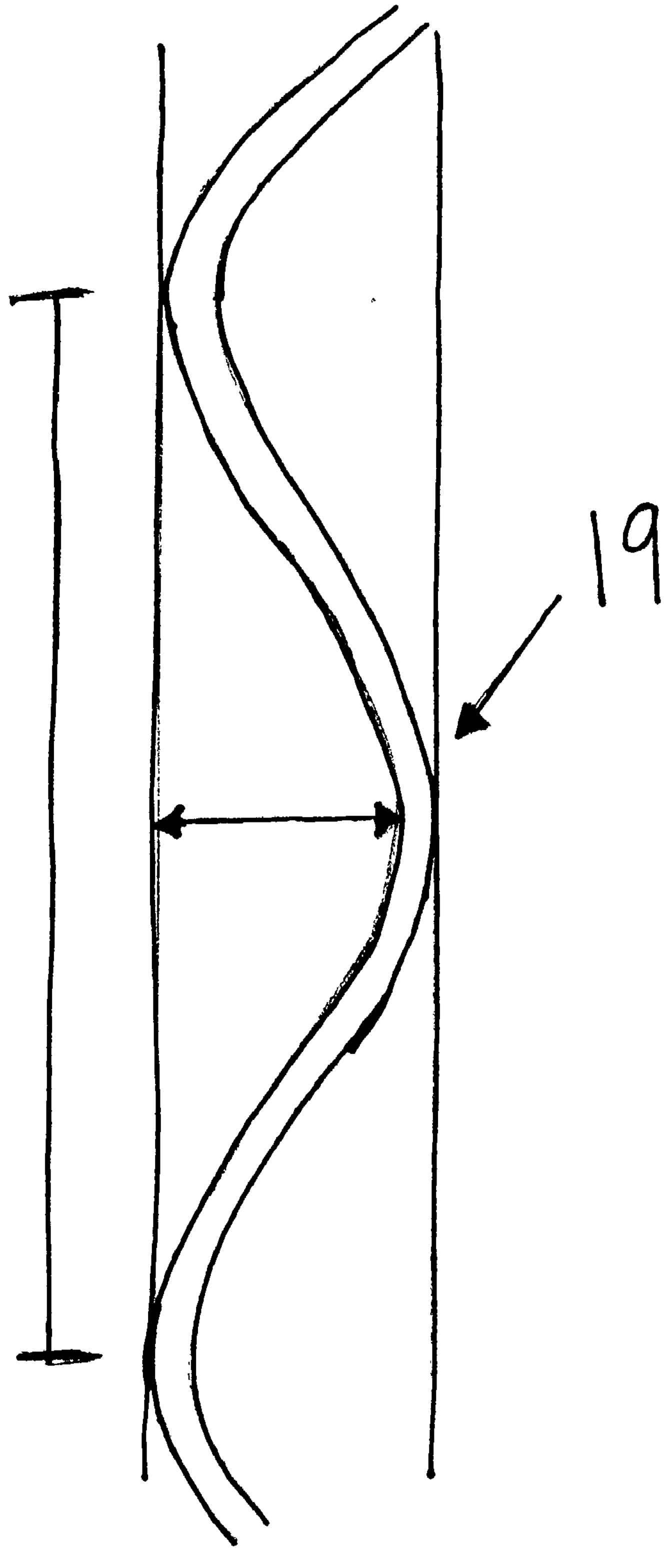


Figure 5B

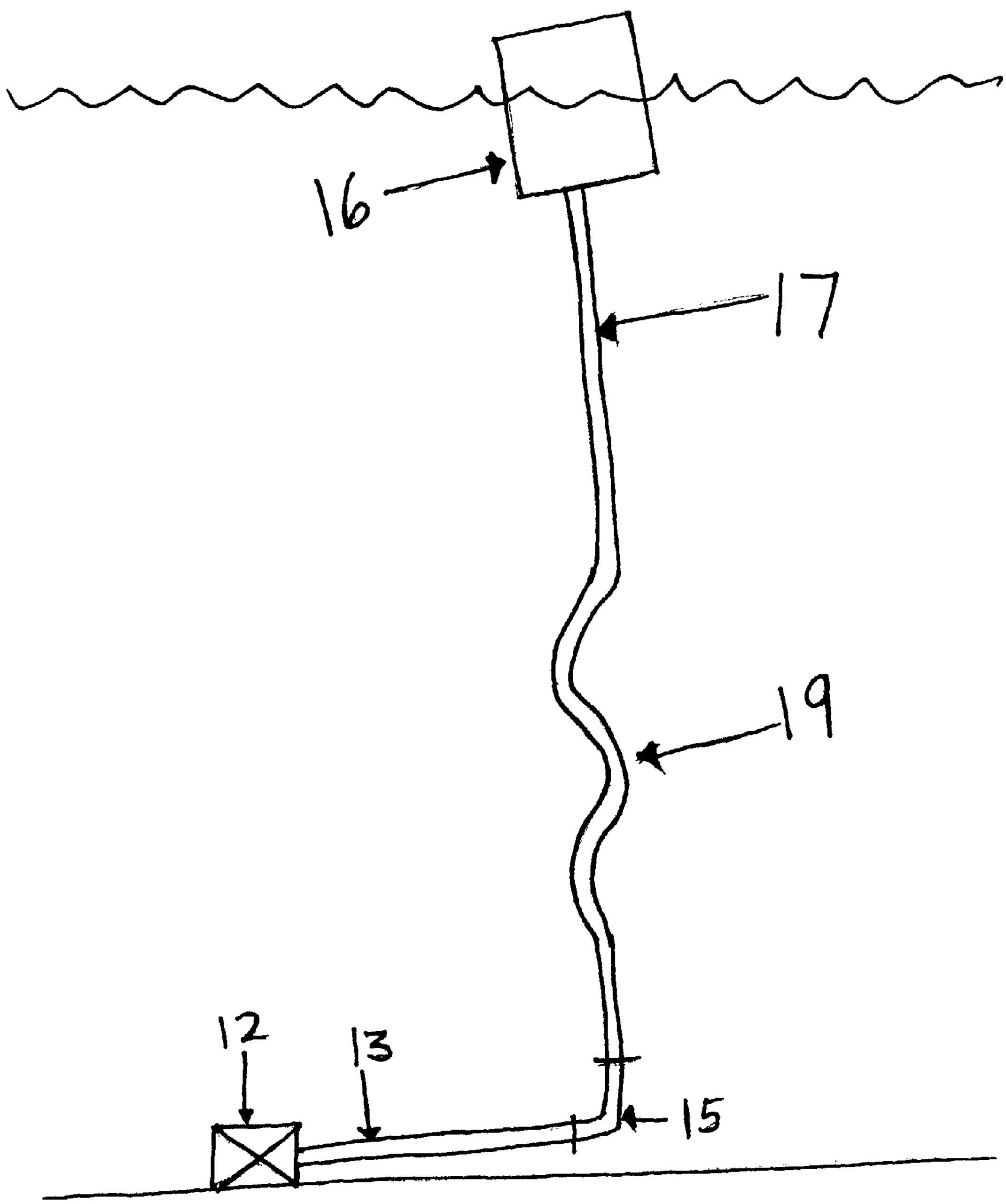


Figure 6

SYSTEM FOR ACCOMMODATING MOTION OF A FLOATING BODY

BACKGROUND

[0001] This invention is generally related to risers that convey fluid from producing wells on the seafloor to a floating structure on the sea surface. This invention is also related to a conduit that is fixed to the seafloor, which must accommodate the motion of a vessel that is connected to it.

[0002] In offshore drilling and production operations carried out from a floating vessel, fluid is conveyed from wells on the seafloor to the vessel stationed on the surface by a conduit often referred to as a "riser." Various methods and mechanisms are used to reduce stresses in risers that are affixed to the moving vessel on the surface and the stationary wellhead at the seafloor. These include using flexible hose for the riser in lieu of steel pipe, supporting a steel riser with hydraulic or electrometric tensioners that accommodate the relative movement of the vessel, buoyancy cans that support the pipe at the top and allow the vessel to move (as shown in, for example, U.S. Pat. No. 4,702,321, incorporated herein by reference) or some combination of these techniques. Another method is by using a steel catenary riser (often referred to as a "SCR") which comprises an extension of the steel riser pipe a sufficient horizontal distance from the vessel such that the pipe forms a rather deep catenary curve. Depending on a number of factors, the SCR can be designed to accommodate some vessel motion.

[0003] The above methods all have disadvantages and limitations. For example, flexible hose is costly, cannot withstand external compressive loads without internal stiffening, and requires bend-restrictor devices at the terminations. The SCR are much less costly and have a long record of reliability; however, their shortcoming lies in motion compensation. The tensioners and buoyancy cans are expensive, and they both require a flexible hose (referred as a jumper line) to accommodate the relative motion between the top of the riser, which sometimes includes a "Christmas tree," and a flow manifold (fixed to the vessel).

[0004] There is therefore a need for a relatively low-cost, simple riser that compensates for the motion of a floating vessel.

SUMMARY OF THE INVENTION

[0005] The above issues are addressed, in various aspects of the invention, using a riser with an elbow.

[0006] According to one aspect of the invention, a system is provided for accommodating motion of a floating-body fixed to a seafloor wellhead. The system comprises: a first riser segment suspended from a floating-body, a second riser segment, and an angled segment for connecting the first riser segment and the second riser segment. In one example embodiment, the first riser segment comprises pre-formed, helical curves in a pre-determined flex portion. In an alternative embodiment, the pre-formed curves comprise pre-formed, single-planar curves. Arched curves comprise an even further embodiment. In another embodiment, the second riser segment comprises at least one pre-determined flex portion (for example, pre-formed curves, helical, single plane arched, etc.). In still a further embodiment, the pre-determined flex portion comprises an essentially straight portion of the riser designed to flex more than other portions of the riser.

[0007] In another aspect of the invention, an apparatus is provided for accommodating motion of a floating-body connected to a substantially vertically-oriented riser section. The apparatus comprises: an angled joint connected to the substantially vertically-oriented riser section, and a pipe connecting a seafloor wellhead to the angled joint. In one example embodiment, the pipe comprises pre-formed curves at least one pre-determined flexing portion. In another embodiment, the substantially vertically-oriented riser section comprises a pre-determined flexible riser section.

[0008] As before, curves of various shapes, and even straight portions, are used in a variety of alternative embodiments.

DESCRIPTION OF THE FIGURES

[0009] **FIG. 1** is a side view of an example of the invention.

[0010] **FIG. 2** is a side view of an example embodiment of the invention.

[0011] **FIG. 3** is an angular view of an example of the invention.

[0012] **FIG. 4** is an angular view of an example of the invention.

[0013] **FIG. 5A** is a side view of an example of the invention.

[0014] **FIG. 5B** is a side view of an example of the invention.

[0015] **FIG. 6** is a side view of an example of the invention.

DESCRIPTION OF EXAMPLE EMBODIMENTS

[0016] According to one example embodiment of the invention, seen in **FIG. 1**, substantially horizontal well entry pipe **13** is in a substantially horizontal connection to the wellhead **12**. Horizontal well entry pipe **13** connects to an inflexible elbow **15** that is also connected to a substantially vertical riser pipe **17**. Vertical riser pipe **17** is connected to a floating-body **16**. Both the horizontal well entry pipe **13** and the vertical riser pipe **17**, although being stiff in comparison to flexible hoses (e.g., steel, in some embodiments), flex or bend in response to the motion of the floating body **16**, so that the forces exerted by the heave or other motion of the floating-body **16** are substantially isolated from the wellhead **12**.

[0017] As used herein, a "substantially horizontal pipe" is mentioned by way of contrast to a substantially vertical riser pipe. The substantially horizontal pipe, however, is anticipated to move through large angles as the vessel heaves, and it may at times have a significant angle to the sea floor.

[0018] Referring now to **FIG. 2**, in another example, a riser pipe spur **18** is seen and comprises a substantially vertical connection to the wellhead **12**. Riser pipe spur **18** is connected to an elbow **15** that is also connected to a vertical riser pipe **17**. In one embodiment, this vertical riser pipe **17** is connected to the floating body **16** (by number of methods) and flexes along energy-absorbent, pre-determined portions in response to the motion of the floating body **16**, thereby reducing the forces exerted on the wellhead **12**. In further embodiments, multiple elbows **15** are used to connect multiple sections of the riser **14**.

[0019] By flexing, as illustrated in **FIGS. 3 and 4**, the energy-absorbent, pre-determined portions of the riser **14** absorb the energy of the heaving floating-body **16** without buckling. The flexing seen in **FIGS. 3 and 4** comprises flexing along a significant potion of the length of the horizontal and vertical riser pipes **13** and **17**. In alternative embodiments, however, pre-determined portions of the riser **14** are designed to flex or bend. In some embodiments, seen in the examples of **FIGS. 6A and 6B**, the pre-determined portion comprises pre-formed curves **19**.

[0020] In **FIG. 5**A, the pre-formed curves **19** comprises an open coil. In one embodiment, this open coil forms a helical curve. The vertical distance between equivalent points in the helical curve is referred to herein as the "curve spacing," and the "curve diameter" refers to the diameter of the cross-sectional area of the curve. In some embodiments, the curve spacing is at least double that of the curve diameter. In one embodiment, the curve spacing increases as the helical curve moves away from the seafloor.

[0021] **FIG. 5B** shows an example embodiment in which the pre-determined portion comprises pre-formed curves **19** in a single plane. In some embodiments, the pre-formed curves **19** are sinusoidal; and, in other embodiments, the pre-formed curves **19** have semi-circular or other shapes. Combinations of such shapes of varying complexity are included in still further embodiments. For example, in one embodiment, the pre-formed curves **19** comprise several connected segments of pipes, while in still other embodiments, the pre-formed curves **19** exist in multiple sections of the riser **14**.

[0022] **FIG. 6** shows an example in which pre-formed curves **19** are formed in a part of the vertical riser pipe **17**. In another, pre-formed curves **19** are formed in the horizontal well entry pipe **15**. In still another embodiment, pre-formed curves **19** are formed in both the horizontal well entry pipe **15** and the vertical riser pipe **17**.

[0023] Referring again to the example in **FIG. 1**, the elbow **15** is substantially inflexible, so all of the force exerted by the floating-body **16** is absorbed by the riser pipes. In some other embodiments, the elbow **15** is somewhat flexible and is able to absorb some of the stress along with the riser pipes. Also in the example of **FIG. 1**, elbow **15** connects the riser pipes at a 90-degree angle, but it connects the riser pipes at larger or smaller angles in some other embodiments, as is needed in a given application.

[0024] In various examples, floating-body **16** comprises a SPAR-type semi-submersible. In other embodiments, the floating-body **16** comprises a floating production storage and offloading (FPSO) system and/or other floating platforms or vessels that will occur to those of skill in the art.

[0025] The riser **14** is at least partially suspended from the floating body **16** in one embodiment. At the elbow **15**, the tension is sufficient to prevent the riser **14** from buckling due to compression resulting from the combined weight of the riser **14** and its contents. The tension in the riser **14** is also sufficient to keep the vertical riser pipe **17** in an essentially vertical orientation to prevent it from clashing with adjacent risers. In one embodiment, the flexing of the riser **14** are the only means for absorbing the force exerted by the motion of the floating-body **16**. In other embodiments, the flexing of the riser **14** is used in conjunction with a floating connection at the floating-body **16**.

[0026] One important benefit derived from including an energy-absorbent, pre-determined portion of the riser **14** is that it adds an additional layer of safety for the structural integrity of the whole riser **14**. If, for example, the top end of the riser **14** should move beyond its normal operating design limits, either horizontally or vertically, the energy-absorbent, pre-determined portion of the riser **14** flexes, without local buckling, and still maintains structural integrity. This situation might occur if, for example, the surface vessel **16** should lose buoyancy due to a damaged tank, if the moorings were to come loose or some other mishap were to occur.

[0027] In one embodiment of a method for installing the riser **14**, the segments are joined by the elbow **15** before the installation begins. In various other embodiments, the segments are connected after the installation has begun, and, in at least one embodiment, the segments are connected once the installation is essentially complete.

[0028] The above embodiments are given by way of example only. Other embodiments will occur to those of skill in the art without departing from the spirit of the invention.

What is claimed is:

1. A system for accommodating motion of a floating body connected to a seafloor wellhead, the system comprising:

a substantially vertical riser segment to be suspended from a floating-body such that a top portion of the substantially vertical riser segment moves as the floating body moves,

a substantially horizontal wellhead entry pipe to be connected to a wellhead, and

an angled segment connecting the substantially vertical riser segment and the wellhead entry pipe such that the angled segment is positioned with respect to the substantially vertical riser segment and the substantially horizontal segment to move in response to motion of the floating body.

2. A system as in claim 1, wherein the substantially vertical riser segment comprises a substantially straight pipe.

3. A system as in claim 1, wherein the substantially horizontal wellhead entry pipe comprises a substantially straight pipe.

4. A system as in claim 1, wherein the substantially vertical riser segment comprises pre-formed, helical curves in a pre-determined flex portion.

5. A system as in claim 1 wherein the substantially vertical riser segment comprises pre-formed single-planar curves.

6. A system as in claim 5 wherein the single-planar curves comprise arched curves.

7. A system as in claim 1 wherein the substantially horizontal wellhead entry pipe comprises at least one pre-determined flex portion.

8. A system as in claim 7 wherein the pre-determined flex portion comprises pre-formed curves.

9. A system as in claim 8 wherein the pre-formed curves comprise helical curves.

10. A system as in claim 8 wherein the pre-formed curves comprise single-plane curves.

11. A system as in claim 8 wherein the pre-formed curves comprise arched curves.

12. A system as in claim 7 wherein the pre-determined flex portion comprises a substantially straight portion formed to flex more than other portions.

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