Feb. 24, 1970 G. W. MORGAN 3,496,898

MARINE RISER STRUCTURE

Filed May 15, 1968 3 Sheets-Sheet 1

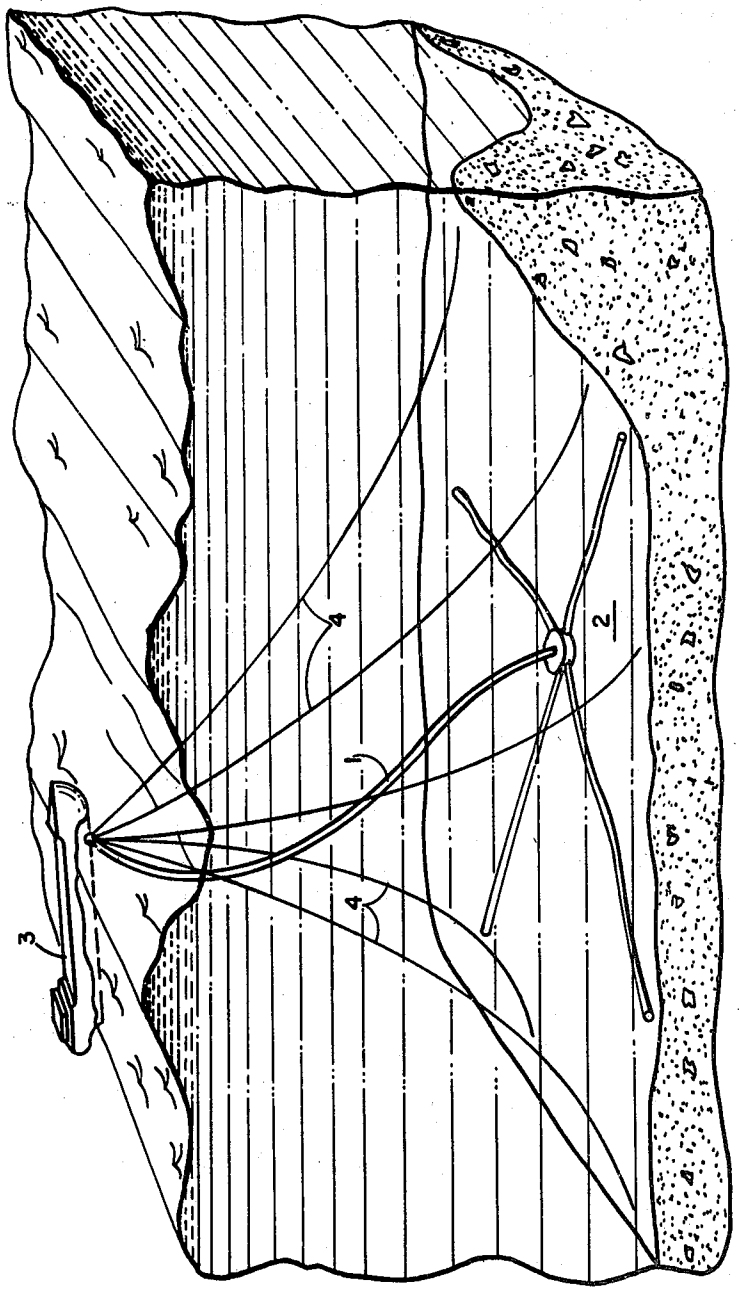


FIG. 1

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MARINE RISER STRUCTURE

Filed May 15, 1968 3 Sheets-Sheet 2

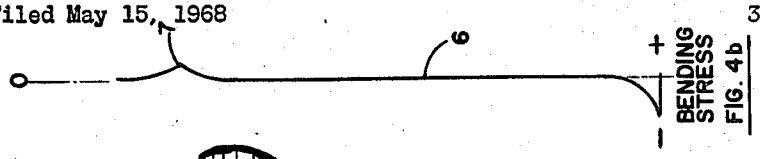


FIG. 4b

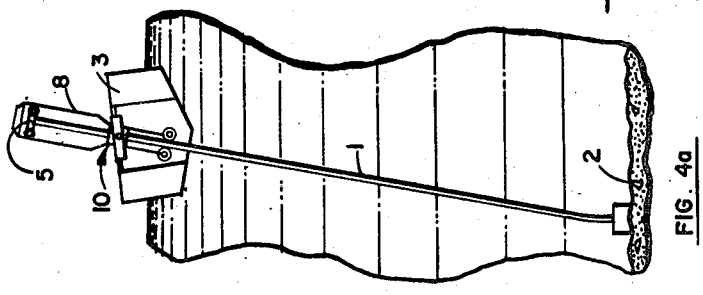


FIG. 4a



FIG. 3b

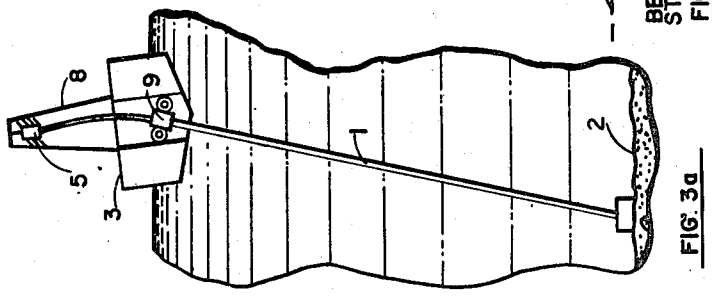


FIG. 3a

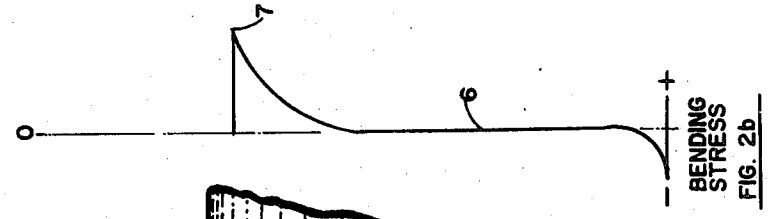


FIG. 2b

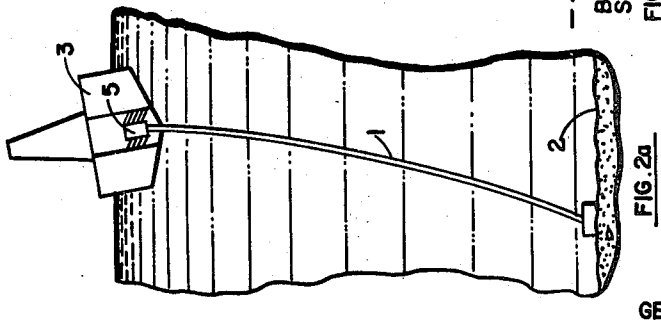


FIG. 2a

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MARINE RISER STRUCTURE

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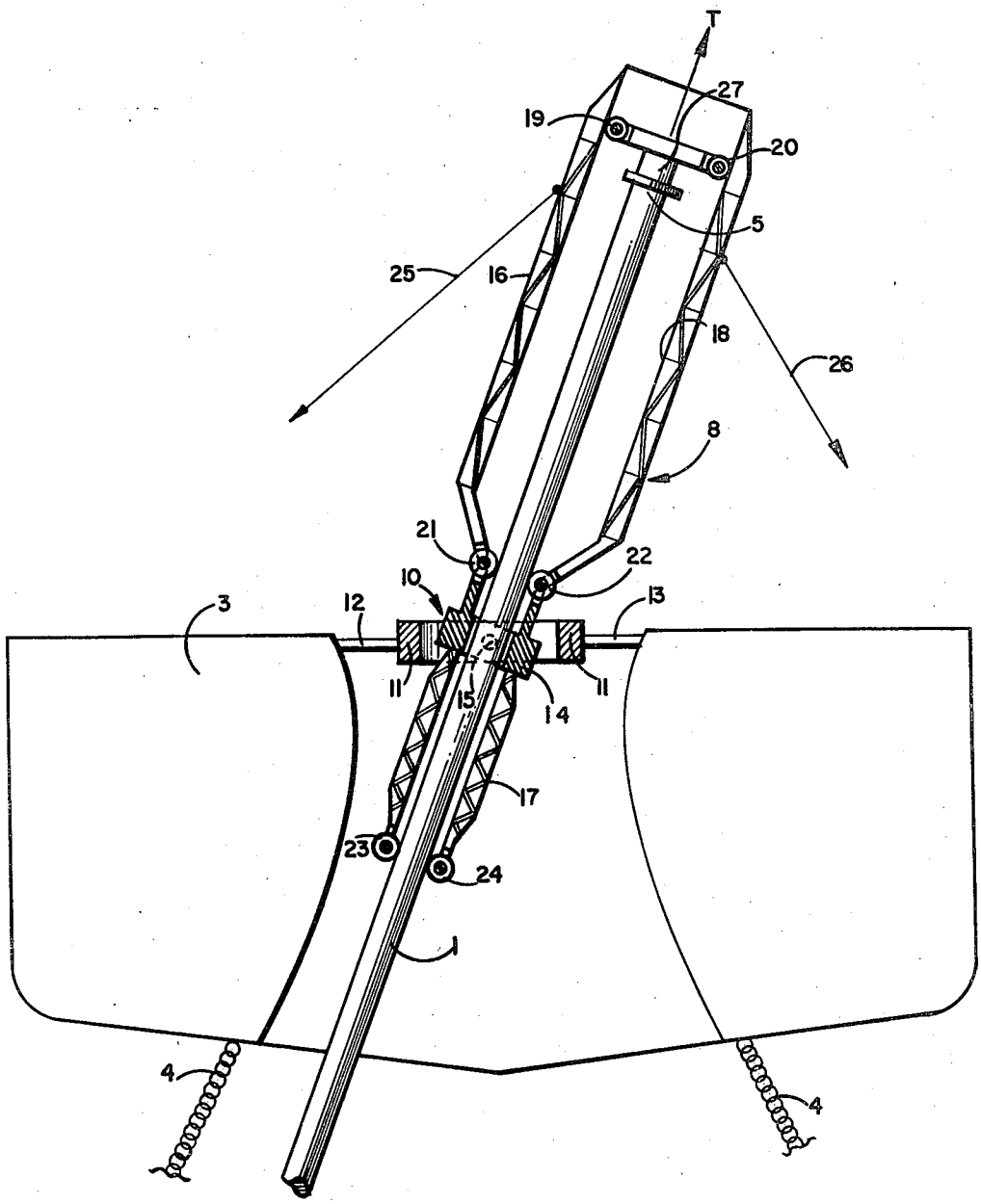


FIG. 5

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United States Patent Office 3,496,898 Patented Feb. 24, 1970

3,496,898

MARINE RISER STRUCTURE

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Filed May 15, 1968, Ser. No. 729,286
Int. Cl. B63b 35/00; E21b 43/01
U.S. Cl. 114—0.5 4 Claims

ABSTRACT OF THE DISCLOSURE

A riser structure originating at the ocean floor is attached to a tower positioned on a floating surface facility, which tower is supported by a two-axis gimbal so that the tower may pivot independently of the motions of the surface facility to permit the upper end of the riser structure to follow the contour of the remainder thereof so as to minimize the bending stresses therein.

BACKGROUND OF THE INVENTION

Field of the invention

The present invention relates to a method and means for attaching a riser structure to a floating surface facility and more particularly, to such a method and means for minimizing the bending moments and other stresses in the riser structure caused by the incompatible motions of the riser structure and the floating surface facility.

Description of the prior art

The last few years have evidenced a significant increase in the investigation and development of the potentials of the oceans of the world. One area of considerable activity has been the drilling of offshore wells to locate oil and other liquids and gases. After the offshore well is drilled, it is necessary to provide a riser connection between the sea floor and a floating surface facility to conduct liquids, gases and electrical power between the sea floor and the surface facility. The surface facility may be a tanker, processing ship, barge or other floating vessel.

While it may appear that it would be a simple matter to provide a reliable riser connection between the sea floor and the floating surface facility, such is not the case. Because of the incompatible motions of the riser structure and the surface facility, substantial forces are placed on the riser structure which, if not properly compensated for, would result in the failure thereof. The principal elements of the general problem relate to riser dynamics, ship dynamics, and mooring system dynamics. Each of these principle elements are subjected to dynamic forces associated with the actual sea state, to hydrostatic forces associated with the corresponding sea depth, and to environmental effects which result in corrosion, abrasion, and degradation of structural material properties. In the riser subsystem, for example, the geometric properties of the riser structure vary constantly with time under the action of the dynamic forces. As a result of the geometric changes, the force-deflection relationships undergo various types of non-linear changes. The same inter-relationship of forces and displacements exists in the mooring subsystem as well as in the ship subsystem. For example, geometrical changes in the ship's position will effect the upper end conditions of the riser and mooring subsystems. Changes in the mooring curvature and bottom conditions will effect the mooring subsystems restraining properties which effect the ship's force-deflection relationships, and so on.

The changing relationships between water particle motions and riser motions in a fully aroused sea form the basis of the riser design problem. The principal problem is to permit the surface facility to respond as necessary to

the action of the sea while permitting a continuous flow of liquids, gases and electrical power through the riser. In rough seas, for example, the bow fairlead on a tanker may travel vertically in excess of 100 feet. In addition, it may not be practical to constrain the horizontal motion of the tanker to less than 10% to 15% of the water depth.

Of the many problems which effect the development of a reliable riser connection, the present invention is primarily concerned with the minimization of the bending stresses in the riser structure. Minimization of these bending stresses involves dynamic excitation control, geometry control and riser flexural rigidity control. On the latter point, flexural rigidity control requires a consideration for the rate of change of flexural rigidity in the riser structure since high stresses are associated with immediate changes in flexural rigidity. The riser structure, at times, will be subjected to very high rates of acceleration and deceleration. Therefore, it is necessary to provide a structure which will tend to minimize the degree of fixidity of the riser structural attachment to the surface vessel. End fixidity of the riser results in extremely high stress levels at the point of attachment. Therefore, the hardware attachment should decouple a large amount of ship motions which are detrimental to the functional performance requirements of the riser. In addition, pitch and roll of the vessel, when added to the angle associated with maximum horizontal excursion, result in excessively high bending stresses in the riser at the point of attachment unless the riser is essentially pin connected to the ship.

Many solutions have been suggested to eliminate the high bending stresses developed in a riser which is fixedly connected to a surface vessel. One proposed technique, known as a mono-mooring terminal system, which permits a moored tanker to weathervane about a single buoy loading terminal, has been developed and is operational for multiple off-loading lines in water depths up to approximately 100 feet. In this type of system, a large cylindrical buoy acts as a floating stationary platform for a rotating deck above. The deck supports the product piping and deck handling gear. A center well extends through the buoy and a hydraulic swivel mechanism is located within the center well. The rotating product piping enables the tanker to weathervane about the buoy while maintaining continuous product flow.

One problem with such a configuration is that the size of the buoy limits the water depth and the turbulence of the sea with which it may be used. As the water depth increases and the sea becomes more turbulent, larger and larger mono-mooring terminals are required to develop the necessary mooring stability. The result may well be a mooring buoy having a size equivalent to that of the tanker. This creates the problem that the tanker may engage the buoy and one or both may be damaged. Fouling and damaging of the hoses between the buoy and the tanker is also a potential hazard.

Another proposed technique for eliminating the high bending stresses associated with a riser which is rigidly connected to the surface facility employs a semi-fixed connection at the surface facility. A suitable tower is fixed to the ship and supports the end of the riser at the top thereof. Bending moment relief is provided by permitting lateral motion and rotation of the connection point at the lower end of the tower. However, while this technique substantially eliminates the bending stresses at the lower connecting point, substantial bending stresses still exist between the lower and upper connecting points.

SUMMARY OF THE INVENTION

According to the present invention, these problems are solved by providing a method and means for attaching a riser structure to a floating surface facility which will

minimize the bending moments and other stresses therein caused by the incompatible motions of the riser structure and the floating surface facility. The present invention resides in providing a two-axis gimbal to support the riser tower on the surface facility so that the tower may pivot about a point intermediate the ends thereof to minimize the bending tresses in the rised. By providing a gimballed tower which may pivot independently of the surface facility, the tower and the upper end of the riser attached thereto may freely rotate so that the upper end of the the riser structure and thereby substantially minimize the bending moments at the upper end thereof.

It is, therefore, an object of the present invention to provide a method and means for attaching the upper end of a riser structure to a floating surface facility.

It is a still further object of the present invention to such a method and means which will minimize the bending moments and other stresses in the riser structure caused by the incompatible motions of the riser structure and the floating surface facility.

It is a still further object of the present invention to provide means for attaching the upper end of a riser structure to a floating surface facility, which means comprises a gimballed tower.

Still other objects, features and attendant advantages of the present invention will become apparent to those skilled in the art from a reading of the following detailed description of the preferred embodiment constructed in accordance therewith, taken in conjunction with the accompanying drawings wherein like numerals designate like parts in the several figures and wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a perspective view of a portion of the ocean, a surface facility and a riser structure illustrating the relationship therebetween;

FIGURES 2*a*, 3*a* and 4*a* are schematic diagrams illustrating the conditions of fixed, semi-fixed and gimballed connections, respectively, between the upper end of the riser structure and the surface facility;

FIGURES 2*b*, 3*b* and 4*b* are a series of curves showing the bending moments associated with the riser structures of FIGURES 2*a*, 3*a* and 4*a*, respectively; and

FIGURE 5 is a simplified, cross-sectional view of a gimballed tower constructed in accordance with the teachings of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings and, more particularly, to FIGURE 1 thereof, there is illustrated the general aspect of the real-life overall problem. In FIGURE 1 it is desired to attach a riser structure, generally designated **1**, which originates at the sea floor **2** to a floating surface facility **3** so as to conduct hydrocarbon products and utilities between sea floor **2** and facility **3**. Surface facility **3**, which may be a tanker, processing ship, barge or other floating vessel, is moored by a plurality of mooring lines **4**. The principal problem is to permit surface facility **3** to respond as necessary to the action of the sea while allowing a continuous flow of liquids, gases and electrical power through riser **1**.

Referring now to FIGURE 2*a*, there is shown, diagrammatically, the connection geometry between riser **1** and surface facility **3** where the upper end **5** of riser **1** is fixedly connected to surface facility **3**. In such cases upper end **5** of riser **1** is constrained by the motion of facility **3** and its motion is independent of the physical position of riser **1**. As shown in FIGURE 2*b*, such a fixed connection results in a bending moment curve **6** which has a substantially high peak value **7** at the point of connection between upper end **5** of riser **1** and vessel **3**.

Referring now to FIGURE 3*a*, there is shown, diagrammatically, the connection geometry under circumstances where a tower **8** for supporting upper end **5** of riser **1** is fixedly connected to surface facility **3** yet where moment relief is provided by permitting lateral motion of riser **1** and rotation of a connecting point **9** at the base of tower **8**. As shown in FIGURE 3*b*, such a configuration is effective to decrease the maximum value **7** of bending moment curve **6** and to relocate it at a point intermediate end **5** and point **9**.

Referring now to FIGURES 4*a* and 4*b*, according to the present invention, it is proposed to substantially decrease even further the maximum value **7** of bending moment curve **6** by providing a configuration wherein tower **8** is connected to surface facility **3** by a two-axis gimbal, generally designated **10**, which will permit tower **8** to rotate about the two axes defined by gimbals **10** so that the upper end **5** of riser **1** may pivot independently of the motions of facility **3** to follow the remaining contour of riser **1**.

Referring now to FIGURE 5, there is shown a gimballed tower constructed in accordance with the teachings of the present invention. Tower **8** is connected to surface facility **3**, which is moored by lines **4** to the sea floor, by means of two-axis gimbal **10**. Gimbal **10** consists of an outer gimbal **11** which is rotatably connected via axles **12** and **13** to surface facility **3**. Outer gimbal **11** is permitted to rotate about the axis defined by axles **12** and **13** to give tower **8** a first degree of rotational freedom. An inner gimbal **14** is rotatably connected via axles **15** and **15'**, the latter not being shown in FIGURE 5, to outer gimbal **11** so as to provide tower **8** with rotational freedom about a second orthogonal axis defined by axles **15** and **15'**.

According to the preferred embodiment, tower **8** consists of an upper section **16** and a lower section **17**. Upper section **16** has an inner surface **18** which is adapted to be contacted by a pair of guide rollers **19** and **20** which are connected to upper end **5** of riser structure **1**. Suitable tension, generally designated **T**, is applied to upper end **5** of riser structure **1** so as to eliminate the slack in riser structure **1** and to maintain the desired stress conditions therein. In this manner, as surface facility **3** moves upwardly, an increase in the tension in riser structure **1** can be avoided by upper end **5** thereof moving downwardly with respect to tower **8**. Guide rollers **19** and **20** roll along inner surface **18** of tower **8** to guarantee the smooth motions of riser **1** within tower **8**. To provide further support for riser structure **1** as it moves vertically within tower **8**, a second pair of guide rollers **21** and **22** may be connected to the lower end of upper section **16** of tower **8** immediately above gimbals **11** and **14**. Further support for riser structure **1** is provided by lower section **17** of tower **8** which is connected at its upper end to inner gimbal **14** and which supports, at its lower end, a third pair of guide rollers **23** and **24**. Through the combination of rollers **19–24**, riser structure **1** may freely and easily move through tower **8** in response to the forces on riser structure **1** caused by the motions of ship **3** and the tension at the upper end **5** thereof.

Gimbals **11** and **14** provide tower **8** with two degrees of rotational freedom to thereby substantially minimize the bending moments and other stresses in riser structure **1**. To prevent excessive excursions of tower **8** and to provide damping of the motions of tower **8** under conditions of high acceleration and deceleration, tower **8** may be connected to a suitable compensating damping system via lines **25** and **26**, which also may be locked firmly in the vessel transport mode to support the tower prior to connection with a riser system. In addition, a suitable swivel **27** may be connected to upper end **5** of riser **1** to eliminate torsion stresses in riser **1** as vessel **3** rotates.

While the invention has been described with respect to a preferred physical embodiment constructed in accordance therewith, it will be apparent to those skilled in the art that various modifications and improvements

may be made without departing from the scope and spirit of the invention.

I claim:

1. Means on a floating surface facility for supporting the upper end of a riser structure originating at the ocean floor comprising in combination:

a two-axis gimbal means operatively connected to said surface facility;

a tower means having an upper and a lower section connected to said gimbal means and adapted to receive said riser structure;

a pair of guide rollers connected to said upper section of said tower and another pair of rollers connected to said lower section of said tower in contact with said riser structure to guide the movement of said riser structure within said tower so as to minimize bending stresses on said riser.

2. The invention according to claim 1 wherein the upper portion of said tower is connected on one side of said gimbal means and the lower portion of said tower is connected to the other side of said gimbal.

3. The invention according to claim 2 wherein said second pair of guide rollers is attached to the lower portion of said tower.

4. The invention according to claim 3 and further comprising:

a third pair of rollers connected to the upper portion of said riser to further guide said riser structure.

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TRYGVE M. BLIX, Primary Examiner

U.S. Cl. X.R.

175—7

PO-1050
(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,496,898 Dated February 24, 1970

Inventor(s) George W. Morgan

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

COLUMN 3:

In line 7, "rised" should be --riser--.

In line 11, following "riser" and before "structure" insert the following:

--can position itself to conform to the remainder of the riser--

Line 16, after "to" insert --provide--.

SIGNED AND
SEALED
AUG 18 1970

(SEAL)
Attest:

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Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents