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[11] **3,834,432**

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[54] **TRANSFER SYSTEM FOR SUBOCEANIC OIL PRODUCTION**

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[52] **U.S. Cl.** **141/388,** 141/279, 137/236, 137/577

[51] **Int. Cl.** **B65b 1/04**

[58] **Field of Search** 177/236; 61/1, 46, 46.5; 141/279, 387, 388, 577; 137/578, 579

[56] **References Cited**

UNITED STATES PATENTS

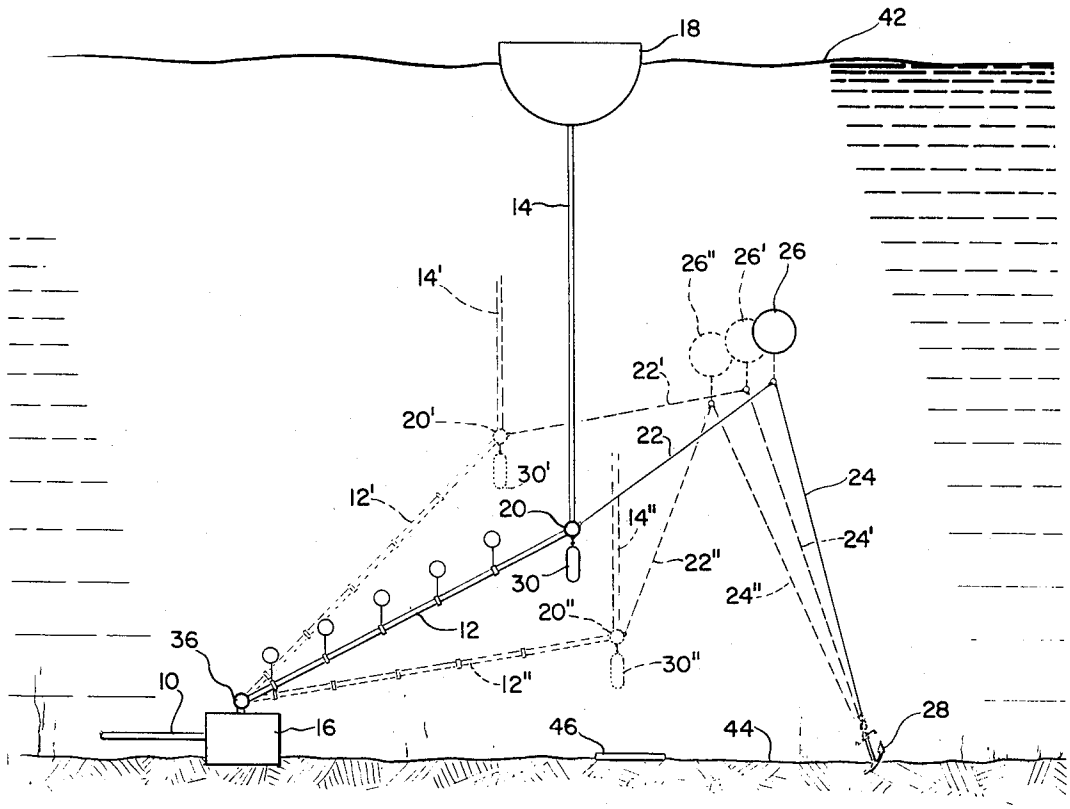
2,955,626	10/1960	Hartley	137/236 X
2,986,888	6/1961	Borrmann	61/46 X
3,359,741	12/1967	Nelson	141/279 X
3,409,055	11/1968	Bily	137/236 X
3,479,673	11/1969	Manning	141/387
3,517,110	6/1970	Morgan	61/46 X

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Attorney, Agent, or Firm—Gausewitz, Carr & Rothenberg

[57] **ABSTRACT**

A transfer system for offshore petroleum production has a vertically movable riser extending from a collection tank on the ocean floor to a storage tanker on the ocean surface. The riser is releasably attachable by a pivotal connection to the tanker during flowing operation and disconnectable during storms or otherwise violent sea states. In the disconnected mode, the riser remains submerged under the ocean surface to avoid excessive structural loading. The riser is articulated and moored by a system of weights and floats to maintain tension within acceptable stress limits throughout a wide range of changes in vertical and some horizontal movement of the tanker.

5 Claims, 6 Drawing Figures

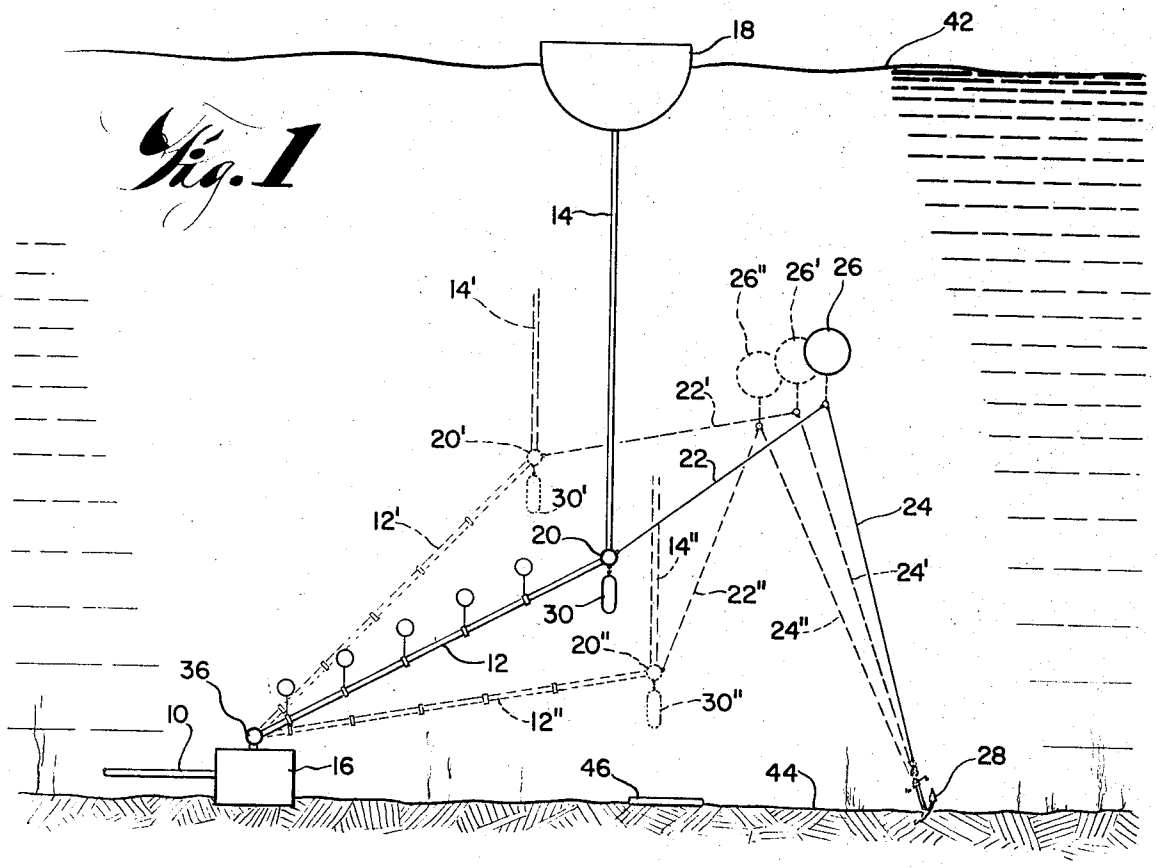


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Fig. 1



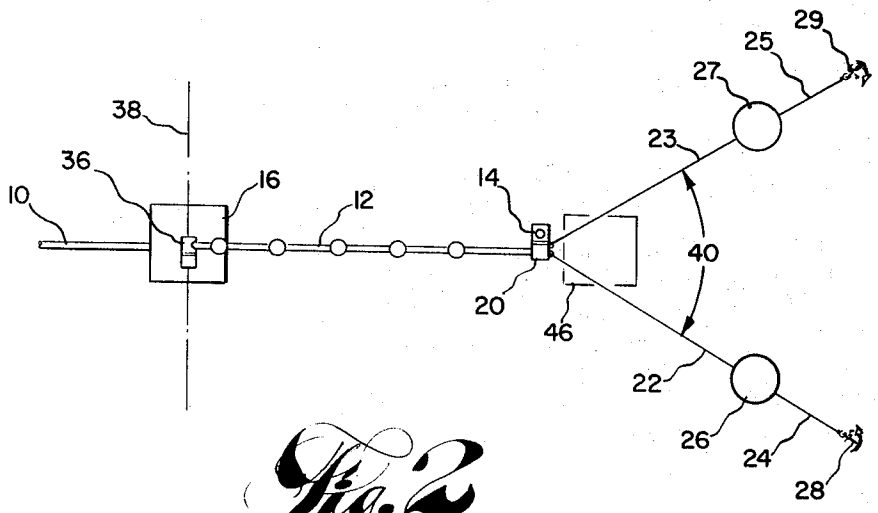


Fig. 2

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Fig. 6

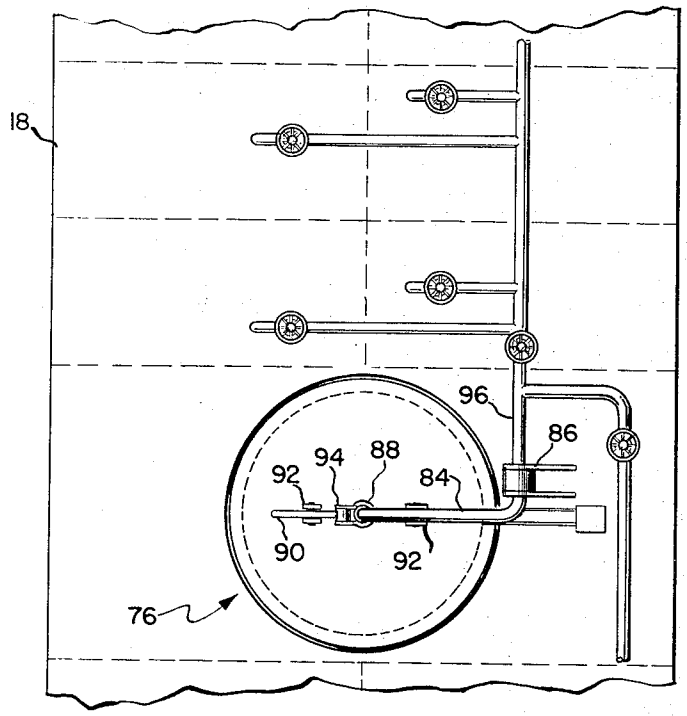
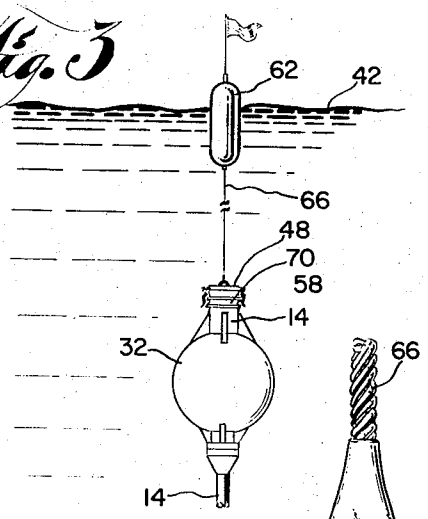


Fig. 3



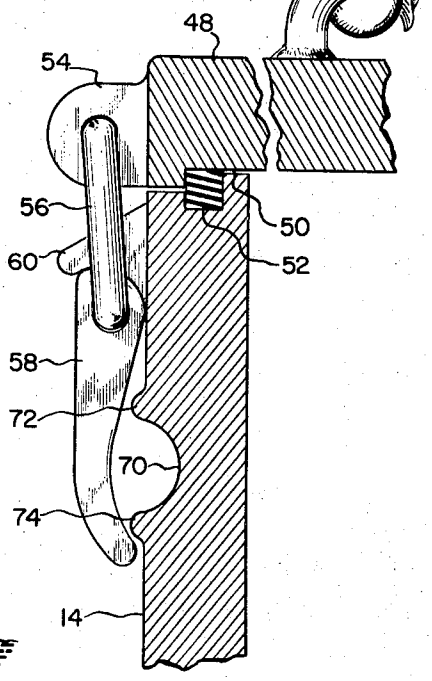


Fig. 4

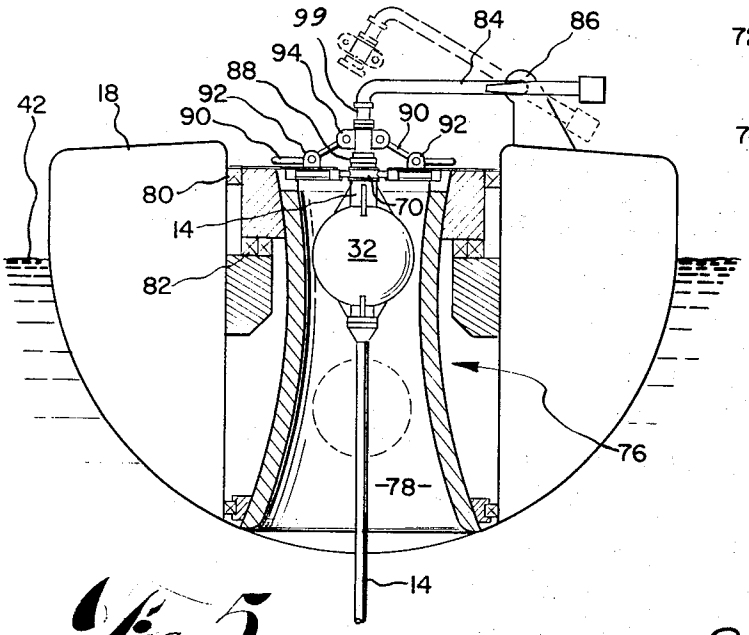


Fig. 5

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TRANSFER SYSTEM FOR SUBOCEANIC OIL PRODUCTION

BACKGROUND OF THE INVENTION

In offshore petroleum production, offloading of crude oil collected from various points on the ocean floor to a storage tanker or other floating facility is necessary. One method in current wide-spread use involves attachment of a riser to a floating swivel buoy which in turn forms a connection point for storage tankers. During storms or severe sea states, the tanker can be disconnected from the buoy, but the buoy can thereafter tear loose from the riser resulting in damage and possible complete loss of the riser.

Another severe problem in the use of risers is associated with their particular sensitivity to structural overstress, especially in waters of great depth or in offshore locations characterized by wide variation of tide levels. Thus, when a tanker heaves upward and downward due to surface wave conditions, the riser connected to such tanker cannot usually respond to such movement at a sufficient rate to accommodate the resulting loads, although risers are generally stronger under tensile loads than any other type loading. During the downward displacement of the tanker, compression forces are applied to the riser which tend to move the same downwardly. The huge length, inertia and relative inflexibility of the riser as well as tremendous hydrostatic pressures severely retard its downward movement through the water, whereby compression loads identified with the mentioned operating conditions involve greater risk of damage than any other type of load or stress imposed thereon. Distortion of the riser such as identified with column bending in beams or the like or any distortion resulting in curvature of the riser cannot be accommodated in view of its mass and axial rigidity.

SUMMARY OF THE INVENTION

The invention contemplates a riser consisting essentially of two separate runs or links **12** and **14** for communicating between a collection or storage tank **16** on the ocean floor and a tanker **18** on the ocean surface. Links **12** and **14** are both substantially straight and are joined to each other by a pivotal connection **20.** Diverging mooring lines connect joint **20** with two floats **26, 27** and two anchors **28, 29,** respectively, as shown in FIG. **2,** to maintain link **12** substantially under tension throughout a relatively wide range of vertical and horizontal displacements of joint **20** as suggested in FIG. **1.** Weighted mass **30** is secured to joint **20** to apply downward force to vertical link **14,** while upward force is applied to the same riser link by buoyant mass or float **32,** thus maintaining this portion of the riser under continuous tension during the mentioned range of movement. The upper end of riser **14** is releasably connected to tanker **18** in the offloading operation, and when disconnected therefrom remains submerged under the ocean surface and therefore less exposed to violent forces associated with stormy seas or collision with surface vessels.

Connection of riser **14** with tanker **18** occurs through a mooring swivel **76** on the storage tanker, at the top of which suitable locking means and conduit flow connections are situated.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a side elevational schematic view of the riser and mooring system contemplated in this case,

FIG. **2** shows a top plan view of the system shown in FIG. **1,**

FIG. **3** shows a detailed view of the upper end of the riser shown in FIG. **1,** but in the disconnected mode,

FIG. **4** shows a fragmentary view, partly in cross-section, of a detail from the structure shown in FIG. **3,**

FIG. **5** shows a transverse view, partly in cross-section, through a storage tanker connected to the riser shown in FIGS. **1** and **2,** and

FIG. **6** is a top plan view of the connection system shown in FIG. **5.**

DESCRIPTION OF THE PREFERRED EMBODIMENT

From FIG. **1,** it may be seen that the invention in this case contemplates and includes a collection or storage container **16** for oil or gas accumulated from one or more suboceanic well drillings (not shown) supplied to tank **16** by one or more conduits as suggested by conduit **10.** A transfer riser consisting of two sections or links **12** and **14** communicates the internal area of tank **16** with a storage tanker or other floating facility **18** on the ocean surface. Riser link **12** is operatively joined to tank **16** through pivotal joint **36** which may take any convenient form known to the prior art, including joint **17** shown in U.S. Pat. No. 3,236,266 issued Feb. 22, 1966 and permitting rotational movement of link **12** in a substantially vertical plane perpendicular to horizontal axis **38** through joint **36** as shown in FIG. **2.** Link **12** of the riser is connected to link **14** through a second pivotal joint **20** which is movable in an arc defined by a center of rotation coinciding with axis **38.** The arcuate path of movement involves both vertical and lateral displacement of joint **20** as suggested by the dash lines in FIG. **1.** Restraining means are provided to limit the transition rate at which movement of joint **20** may occur, the stated means including relatively heavy mass or weight **30.** Link **12** is rendered neutrally buoyant by suitable hydrostatic balance means such as by securing any required number of floats spaced along the length of link **12** as may be necessary to compensate for the weight and mass distribution of riser link **12,** which will naturally include due consideration of the ocean depth and displacement volume of link **12** in any particular installation.

Due to the particular sensitivity of riser links **12** and **14** to damage by compressive loads applied axially thereto, means are provided in this case to maintain each of the separate links under substantially axial tension. The stated means includes one or more mooring line connections between joint **20** and one or more anchors or dead weights. Preferably, a minimum of two separate mooring line connections are used to apply tensile loading of link **12.** Thus, referring to FIG. **2,** lines **22** and **23** are attached to joint **20** and connect the same with buoyant masses or floats **26** and **27,** respectively. Mooring lines **24** and **25** each connect floats **26** and **27** with separate anchor or deadweight means **28** and **29,** respectively. Anchor means **28** and **29** are positioned on the ocean floor equidistantly from the longitudinal axis of riser link **12** so that lateral movements of link **12** either in a clockwise or counterclockwise di-

rection about joint **36** as shown in FIG. **2** will be resisted by substantially equal reaction loads in lines **22** and **23.** In achieving the foregoing action affects, the included angle **40** between lines **22** and **23** should preferably be within a range from 20° to 90°, the higher range limit being preferred. Tensioning of riser **12** is achieved by both of the separate branches in the same manner and may be illustrated by the one shown in FIG. **1** comprising elements **22, 24, 26,** and **28.** Due to buoyancy of float **26,** it will be understood that tension is maintained in lines **22** and **24,** for example, connected to joint **20** and anchor **28,** respectively, and that a force component due to the stated tension in line **22** pulls joint **20** generally toward the right in the view shown by FIG. **1.** Since joint **20** is structurally connected to link **12,** the pulling force thus applied to the joint results in tensile loading of link **12** as the link is unable to move axially due to the restraint offered by its connection with joint **36** and stationary tank **16.** The vertical position of joint **20,** to which downward pulling force is continuously maintained by attachment of weight **30** thereto, is dependent upon the location of the upper end of riser link **14,** which in turn depends upon the buoyancy characteristics of riser buoy **32** in the disconnected mode or the position of tanker **18** when the riser is connected thereto.

In the connected mode suggested by FIG. **1,** it will be understood that ocean surface **42** will cause variations in the vertical position of tanker **18,** either through wave action or tides, and also through loading of the tanker as its hold is filled. Changes in the vertical position of tanker **18** with respect to the ocean floor **44** during oil transfer operation of the riser will result in displacement of joint **20** along the arcuate path within which the joint is movable. If, for example, tanker **18** heaves upwardly from the initial position shown in FIG. **1,** upward force transmitted through riser **14** will pull joint **20** upwardly, and such upward movement will necessarily result in lateral movement of riser **14** and joint **20** due to the restraint offered by riser portion **12** through its connection with the joint. The stated displacement due to upward heaving of tanker **18** is suggested by dashed line **14'** denoting the displaced position of riser **14** toward the left in FIG. **1.** In the stated condition of displacement, float **26** will be forced in a generally downward direction as lines **22** and **24** attached thereto are pulled into closer linear alignment by movement of joint **20** with respect to stationary anchor means **28.** The displaced position of float **26** due to movement of riser **14** and joint **20** toward the left in FIG. **1** is suggested by reference numeral **26'.** In the displaced condition thus represented by numerals **14'** and **26'** in FIG. **1,** it will be understood that tensile force is continuously maintained axially through both riser links **12** and **14** due to the horizontal force component of the tension in lines **22** and **24** and through the continuous downward pull applied to joint **20** by mass **30.**

Downward heaving of tanker **18,** to which riser link **14** is connected at its upper end, would result in corresponding downward movement of joint **20** due to the continuous force applied to joint **20** by mass **30.** The stated downward movement of joint **20** would be accompanied by lateral movement of riser **14** toward the position designated by dashed line **14''** to the right as shown in FIG. **1** due to the continuous rightward force applied to joint **20** by float **26** and transmitted through **22.** Downward movement of joint **20** in the foregoing manner would cause corresponding downward movement of float **26** to the position suggested by reference numeral **26''** by force transmitted through line **22** extending between the joint and the float. In the displaced condition thus denoted by reference numerals **14''** and **26''** in FIG. **1,** it will be understood that riser links **12** and **14** are both continuously maintained under tension due to the forces respectively applied thereto by float **26** and mass **30,** respectively. It may incidentally be noted that the position of the structure shown in FIG. **1** and identifiable with reference numerals **14''** and **26''** is the one normally assumed by the riser and mooring system when riser **14** is in the disconnected mode as discussed more fully below. In the foregoing disconnected position, mass **30** may descend so far as to touch ocean floor **44,** which in many suboceanic locations may comprise a semi-solid surface of mud rather than a smooth hard surface of rock or the like. To prevent embedment of mass **30** by sinkage thereof into a highly tenacious mud mass, a mud mat **46** may be provided in the location suggested by FIG. **1** for supporting mass **30** at its lowermost limit of movement.

Referring to FIG. **3,** the upper end of riser **14** is shown in the disconnected mode characterizing its condition when not in use for transferring products from tank **16** into a storage facility or the like on ocean surface **42.** Hydrostatic balance means in the form of buoyant body **32** comprises a hollow sphere through which riser **14** penetrates is secured or otherwise formed on the riser. The upper terminal end of the riser is provided with a blind hub or cap **48** which seals and closes off the upper terminal end of riser **14.** Cap **48,** as shown more particularly in FIG. **4,** may include a sealing surface **50** adapted to make contact with a sealing member such as flexible ring **52** nested within the upper terminal edge portion of riser **14,** and held firmly in contact therewith by suitable clamping means such as an over-center toggle system as shown in the mentioned figure. The stated system may take any suitable form including those known to the prior art, and illustratively may comprise a projecting boss or lug **54** integrally formed on a cap **48** and supporting a pivotal link **56** having a pivotal lever **58** mounted on the lower end thereof. A projecting flange or curved lug **60** integrally formed or otherwise secure to riser **14** is adapted to receive a rounded portion of lever **58** in securely nesting and load transmitting relationship as shown in FIG. **4.** Rotation of lever **58** into or out of engagement with flange **60** provides secure but easily disconnected holding means between the cap and the riser. As further shown in FIGS. **3** and **4,** cable connection means are provided on cap **48** for securing visual marker buoy **62** thereto. The stated means illustratively include a hollow cleat **64** having cable **66** joined thereto in the manner shown by FIG. **4.** Riser buoy **32** has a predetermined amount of buoyancy which, in combination with the lifting force of buoyant float **32** and the downward forces applied by riser **14** and components attached thereto, result in buoy **32** hanging at a predetermined depth below ocean surface **42** a sufficient amount to avoid the violent effects associated with stormy seas and the like.

As may be further seen from FIG. **4,** the terminal end portion of riser **14** is provided with an annular groove **70** defined by two vertically spaced-apart annular flanges **72** and **74.** Referring particularly to FIG. **5,** at-

tachment means for connecting riser **14** to tanker **18** may conveniently include pivotally mounted mooring swivel **76** supported within a vertical passage **78** through the center of tanker **18.** Suitable bearing support for mooring swivel **76** is provided as schematically shown by bearings **80** and **82,** for example.

In operation, a line (not shown) may be passed through center passage **78** of tanker **18** and secured to marker buoy **62** or cable **66** in order to pull the sealed and submerged end of riser **14** up through mooring swivel **76** for operative attachment as required during the transfer operation. With the riser and buoy **32** thus positioned as shown in FIG. **5,** locking collet or annular flange means mounted on mooring swivel **76** are secured to riser **14** within groove **70** and locked in place by suitable means including those known to the prior art. Blind cap **48** is then removed, exposing the open end of riser **14** and positioning the same substantially in the center of passage **78.** A pivotally mounted section of pipe **84,** with a suitable pipe swivel **99,** appropriately supported on tanker **18** such as by brackets **86** and having mating connection means on the distal end thereof as suggested by flanged end **88** in FIG. **5** is rotated into mating connection with seal **52** at the terminal end of riser **14.** Pivotal links **90** secured at one end to swivelling mooring structure by such means as brackets **92** may be engaged to similar brackets **94** proximate the end **88** of pipe **84** and joined thereto by a pin and clevis connection or the like to hold the pipe **84** in tightly sealed fluid transferring relationship with riser **14.** Alternatively, a toggle system such as shown in FIG. **4** for cap **48** may be used on flange **88** of pipe section **84** to secure the same together. When thus connected, the contents of tank **16** on ocean floor **44** may be transferred into storage tanks and the like aboard tanker **18** through suitable conduits as suggested by pipe **96** in FIG. **6.** Disconnection of riser **14** from tanker **18** is accomplished by simply reversing the connection operation, and includes replacement of cap **48** in the position shown by FIG. **4** and release of the riser together with marker buoy **62** through passage **78** into the submerged state.

We claim:

1. A transfer riser system for use in offshore oil production comprising:

stationary storage means on the ocean floor;

a riser having an upper end disposed near the ocean surface and a lower end connected to said storage means for transferring the contents thereof to the ocean surface;

weight means secured to said riser at a point between the ocean surface and floor;

flotation means operatively associated with said upper end for providing an upward force sufficient to support the weight of the riser plus said weight means and maintaining said upper end near the ocean surface;

said riser having sufficient flexibility to allow said upper end to rise and fall with the wave action and said weight means being sufficiently large to cause said upper end to follow instantaneously the rising and falling waves to allow said flotation means to always maintain a tension force on the riser, said riser further including an upwardly directed portion and a generally laterally extending portion pivotally connected at one end to the lower end of said upwardly directed portion and pivotally connected at the other end to said storage means; and

a mooring system means having means connected to the pivotal connection for maintaining the laterally extending portion under continuous substantially axial tension.

2. The structure set forth in claim **1** above, wherein:

said mooring system means for maintaining said laterally extending portion under tension includes at least one mooring line having one end thereof secured to the pivotal connection between said laterally extending portion and said upwardly directed portion, and having the other end thereof secured to anchor means on the ocean floor.

3. The structure set forth in claim **2** above, wherein:

a buoyant mass is secured to said mooring line intermediate the said ends thereof.

4. The system set forth in claim **2** above, wherein:

said mooring system means comprises at least two diverging mooring lines, each of said lines extending from the pivotal connection to a separate anchor;

each of said anchors being spaced apart a substantially equal distance on either side of the longitudinal axis of said one riser portion.

5. The system set forth in claim **4** above, further including:

separate float means secured to each of said two mooring lines intermediate the connection thereof with said second pivotal connection and said anchors, said float means being displaced downwardly upon said vertical movement of said other riser portion in an upward direction.

* * * * *