United States Patent

[11] 3,602,175

[72] Inventors George W. Morgan
Anaheim;
Bruno R. Naczkowski, Newport Beach,
both of, Calif.

[21] Appl. No. 838,434
[22] Filed July 2, 1969
[45] Patented Aug. 31, 1971
[73] Assignee North American Rockwell Corporation

[54] **OIL PRODUCTION VESSEL**
4 Claims, 5 Drawing Figs.

[52] U.S. Cl. 114/0.5, 9/8, 175/7
[51] Int. Cl. B63b 35/00, B63b 21/52
[50] Field of Search .... 114/0.5, 0.5 F, 0.5 D, 0.5 T, 206, 230; 175/7; 61/46.5; 9/8, 80 P

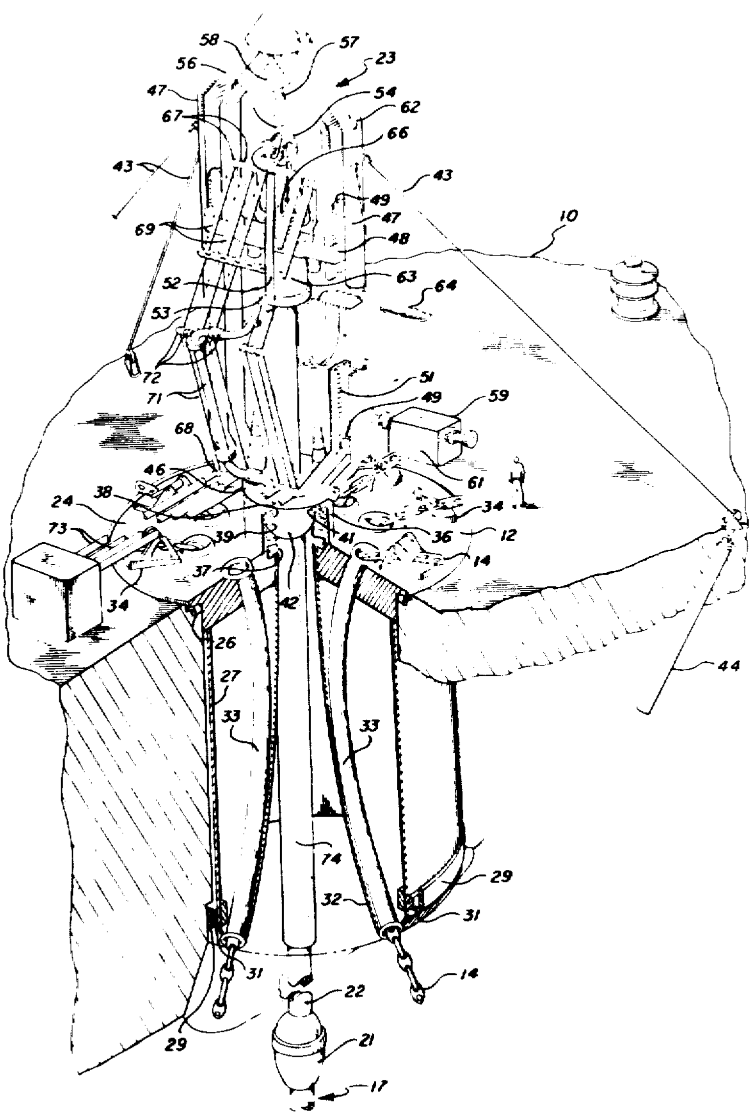
[56] **References Cited**

UNITED STATES PATENTS

3,191,201	6/1965	Richardson et al.	114/0.5 (D) X
3,390,654	7/1968	Bromell et al.	114/0.5 (D)
3,407,768	10/1968	Graham	114/230 X
3,437,064	4/1969	Hunsucker	114/0.5 D
3,440,671	4/1969	Smulders	114/230 X

Primary Examiner—Trygve M. Blix
Attorneys—William R. Lane and Allan Rothenberg

ABSTRACT: A ship is described which is useful for recovery of fluid minerals from the ocean floor. A rotatable mooring swivel through an aperture in the ship's hull near the bow is moored to the sea floor. A riser pipe from the ocean floor passes through the center of the mooring swivel and is connected to a substantially vertically extending tower above the ship. This permits the ship to "weathervane" about the moored plug and riser. The tower rotates with the ship and a fluid swivel is provided between the upper end of the riser and the tower to accommodate relative rotation. In addition, vertical translation of the riser upper end relative to the length of the tower is permitted and the tower is mounted on gimbals for tilting relative to the deck of the ship to remain aligned with the riser end.



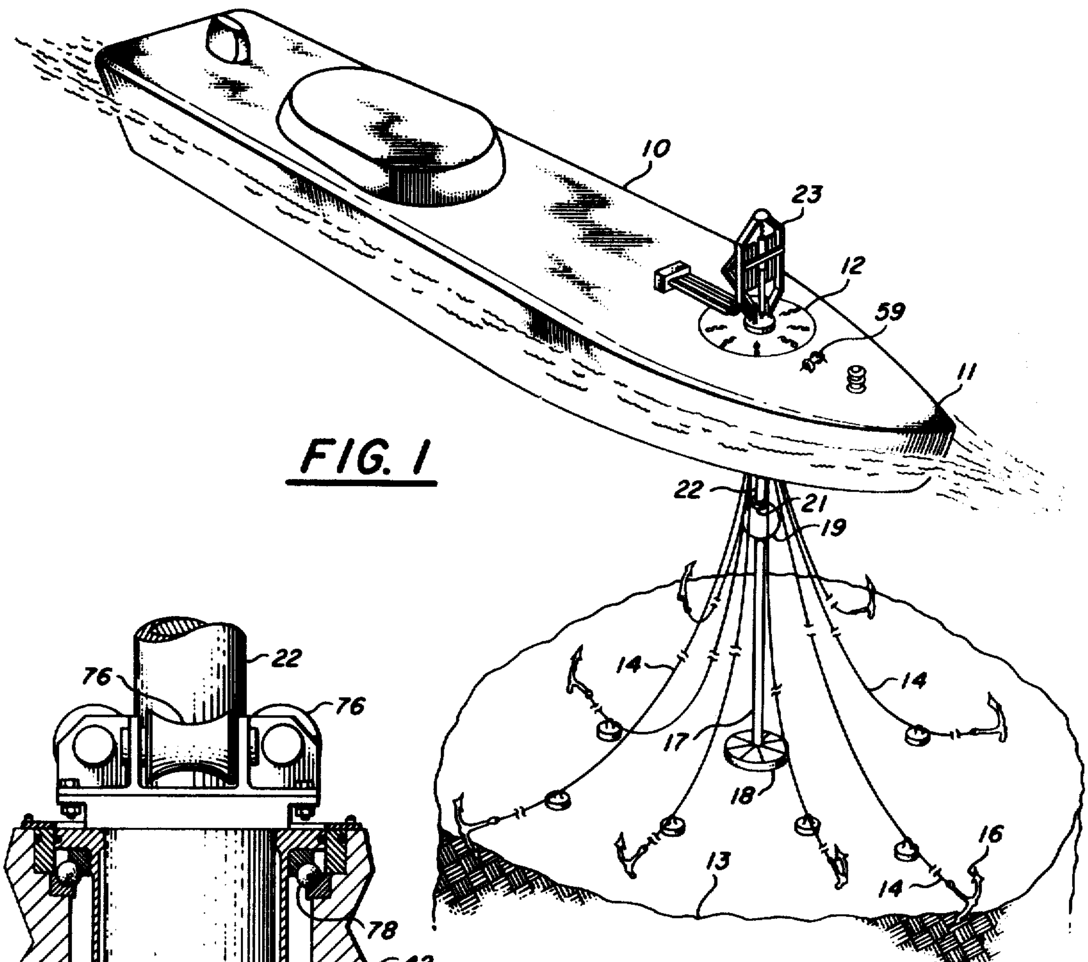


FIG. 1

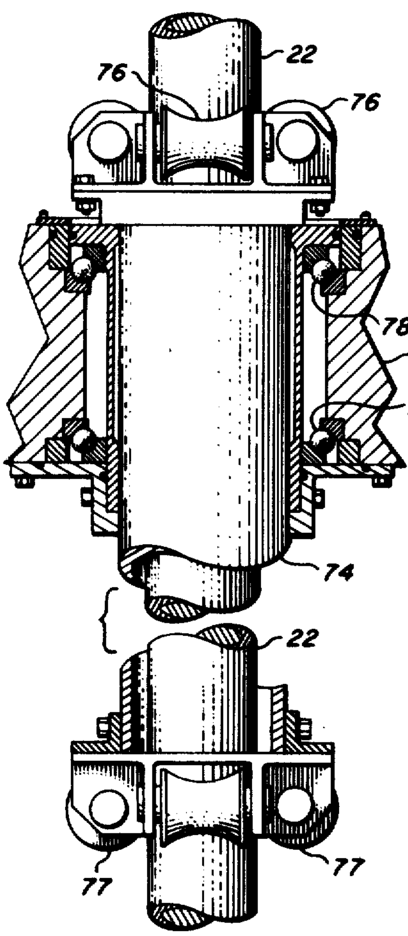


FIG. 4

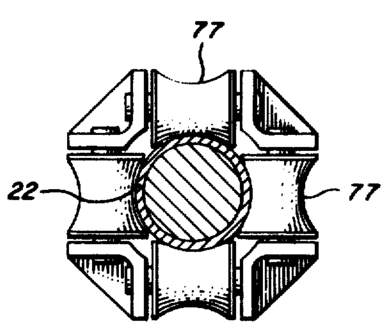


FIG. 5

INVENTORS.
GEORGE W. MORGAN
BRUNO R. NACZKOWSKI
BY
[signature]
ATTORNEY

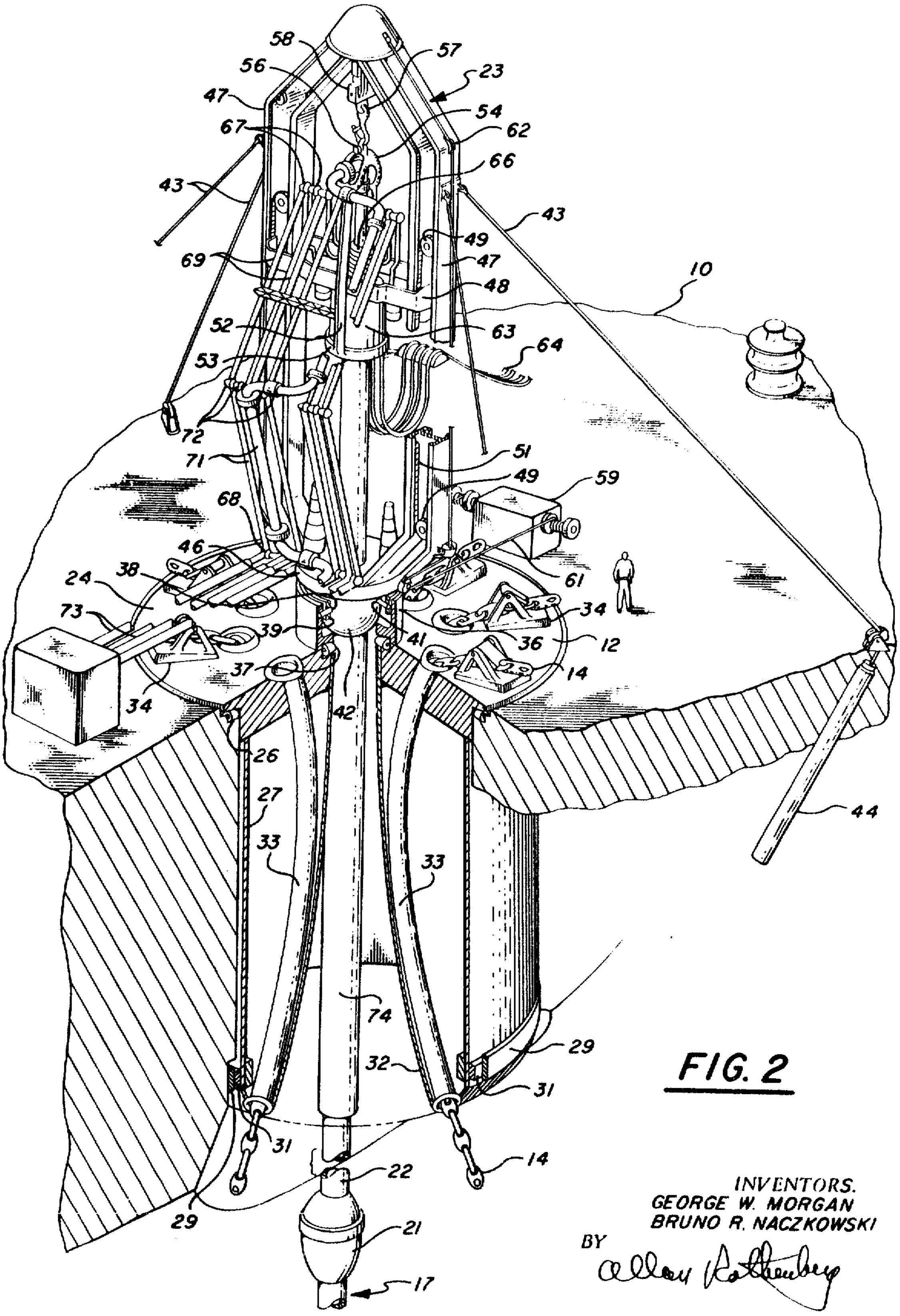


FIG. 2

INVENTORS.
GEORGE W. MORGAN
BRUNO R. NACZKOWSKI

BY Allan Rothenberg

ATTORNEY

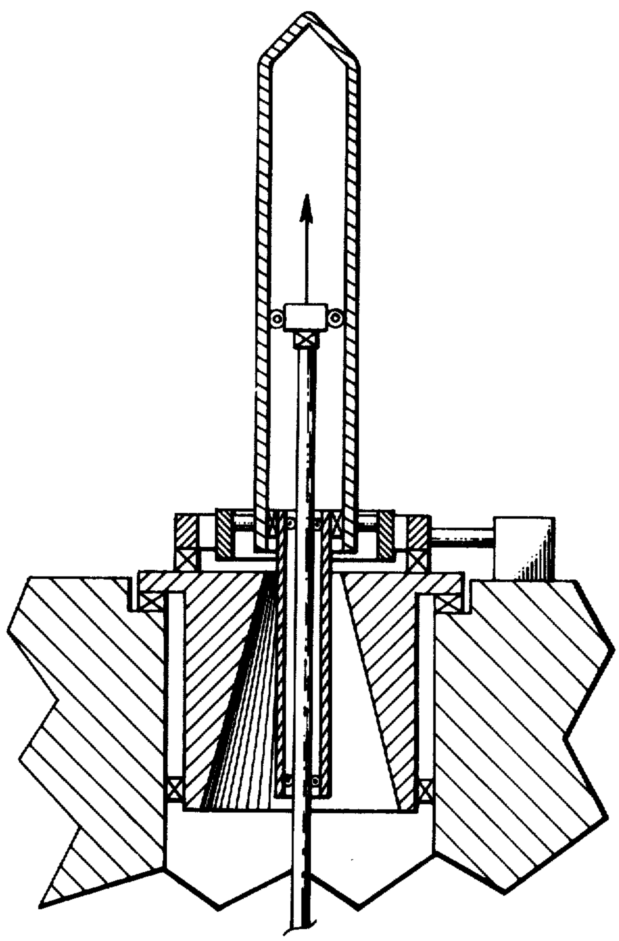


FIG. 3

INVENTORS.
GEORGE W. MORGAN
BRUNO R. NACZKOWSKI
BY
Alan Rattenberg
ATTORNEY

OIL PRODUCTION VESSEL

BACKGROUND

In the offshore production of oil and other subaqueous minerals there is a practical depth limitation for bottom mounted towers that extend above the surface. This practical limit is in the order of about 600 feet and economic considerations may limit the utility of towers to even shallower depths. An alternative to fixed towers is to provide a portion of the production facilities on the sea floor and provide a permanently moored floating facility for the balance. When this is done a substantially vertically extending conduit or riser must be provided between the sea floor and the floating facility. In relatively shallow depths and calm waters many of the problems of permanently interconnecting a floating facility and the sea floor have been solved. However, when the depths become great the stresses involved in a moored ship and fixed riser system become significant and when a permanent mooring is considered, the ability to withstand storm conditions must be provided.

SUMMARY OF THE INVENTION

There is therefore provided in practice of this invention a seagoing tankerlike vessel having a rotatable plug or mooring swivel therethrough near the bow for mooring to the bottom and accommodating a riser passing therethrough. A tower mounted over the plug supports a portion of the upper end of the riser and provides for motion of the riser end along the length of the tower and relative tilt of the tanker relative to the riser in two directions. Fluid swivel means are provided for accommodating rotation between the ship and the riser. Means are further provided for retaining the ship permanently in position during heavy seas without damage to the riser.

DRAWINGS

Objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 illustrates in perspective a ship constructed according to the principles of this invention;

FIG. 2 illustrates in perspective cutaway a mooring swivel and riser tower on the ship;

FIG. 3 shows the swivel and tower schematically;

FIG. 4 illustrates means for accommodating rotation between the tower and the riser; and

FIG. 5 is a view of the means of FIG. 4.

Throughout the drawings like reference numerals refer to like parts.

DESCRIPTION

The general relation of a ship and its parts and a riser incorporating the principles of this invention are illustrated in FIG. 1. As illustrated in this embodiment an ocean going tanker **10** is provided with internal storage tanks (not shown) for a large quantity of crude oil or the like. This tanker **10** is in the same general form as ocean going tankers with a pointed bow **11**. The ship **10** is, however, essentially a barge since no substantial propulsion is provided on board. Propulsion is not required since the ship is substantially permanently moored at an oil producing location and if moving is necessary tugs are employed for propulsion. The pointed bow does, however, serve to minimize the resistance of the ship to environmental forces such as wind, waves and currents. The ship-shaped hull of the storage and production tanker provides excellent stability with a large capacity for storing crude oil and provides acceptable motions in response to wave action.

Since the ship **10** remains on station in the oil producing field at all times, a permanent mooring system is provided which will accommodate high sea states. In order to obtain the lowest load on the mooring system in extreme sea states it is important to orient the ship in the direction of least resistance to the environmental forces such as wind, waves and currents. There is, therefore, provided a mooring swivel **12** for mooring the ship. As hereinafter described in greater detail the mooring swivel **12** is mounted so as to rotate about a substantially vertical axis and the mooring swivel extends completely through the ship's hull from approximately the deck line through to the hull bottom.

In order to provide the maximum directional stability the mooring swivel **12** is located as far forward in the hull of the ship **10** as is possible to allow the vessel to freely "weathervane" without providing auxiliary propulsion to orient the ship. For automatic orientation the distance from the centerline of the mooring swivel **12** to the bow **11** of the ship should not exceed 20 percent of the ship's length measured from the bow to the stern. When the mooring swivel is located in the forward 20 percent of the ship-shaped vessel the naturally occurring moments due to wind, waves and current readily orient the ship in the direction for minimized forces without any auxiliary propulsion. If the swivel is located aft of about 20 percent of the ship's length auxiliary propulsion may be necessary to properly orient the ship. It will be apparent, of course, that if the mooring swivel is located substantially in the center of the ship that auxiliary propulsion is virtually mandatory since little, if any, natural weathervaning can be expected.

The mooring swivel **12** is moored to the ocean floor **13** by a multiple leg, single point mooring system. In this system a plurality of mooring chains **14** are connected only to the swivel **12**, as hereinafter described in greater detail, and extend downwardly from the bottom of the mooring swivel and then outwardly in a radiating pattern to the ocean floor **13**. In practice eight or more mooring chains are employed and extend for long distances on the ocean floor, the drawing of FIG. **1** being compressed considerably for purposes of illustration. As its extremity each of the mooring chains **14** is connected to a conventional anchor **16** on the ocean floor. Additional details concerning the mooring system are contained in copending U. S. Pat. application Ser. No. 838,435, filed July 2, 1969 entitled "Permanent Ship Mooring System" by Bruno R. Naczkowski and assigned to North American Rockwell Corporation, assignee of this invention, and which is hereby incorporated by reference for full force and effect as if set forth in full herein. In the mooring system since the several anchor chains **14** of the mooring legs extend in a radiating pattern from the mooring swivel **12**, this mooring swivel is held in substantially a single location and is effectively prevented from rotating through any substantial degree. The substantially fixed mooring of the mooring swivel to the ocean floor serves to moor the entire ship **10**, and since the swivel is essentially fixed in position any weathervaning of the ship results in relative rotation about a substantially vertical axis between the mooring swivel and the ship.

In order to provide communication with an underwater oil production facility a vertically extending riser **17** is connected to underwater oil production facilities **18** shown schematically in FIG. **1**. A buoy **19** is connected to the riser **17** at a point substantially below the water surface so that the effect of wave action on the buoy **19** and riser is minimized. The buoy provides a substantial tension force on the riser to support the principle weight thereof. A fluid disconnect **21** is provided above the buoy **19** so that the upper portion **22** of the riser can be disconnected from the buoy if desired.

The upper end **22** of the riser passes through the mooring swivel **12** as hereinafter described and illustrated in greater detail and is connected to a tower **23** above the deck of the ship. As is described in greater detail hereinafter means are provided on the tower for accommodating relative motion of the upper end **22** of the riser along the length of the tower **23** and for maintaining a substantially constant tension on the upper end of the riser. In addition, the tower is mounted on a pair of orthogonal gimbals (not shown in FIG. **1**) so that the tower can tilt relative to the ship and remain aligned with the riser during pitch and roll of the ship and surge or displacement of the ship laterally from a position directly over the underwater production facilities 18.

Additional details of the mooring swivel 12 and tower 23 are seen in the perspective cutaway view of FIG. 2 and principle features are set forth schematically in FIG. 3. As illustrated in FIG. 2 the mooring swivel 12 is mounted in an aperture extending from the deck of the ship clear through to the bottom hull line of the ship. This permits the mooring chains 14 to radiate outwardly and downwardly from the ship's hull to the anchor points without interference with any portion of the ship's hull which is therefore free to weathervane about the mooring swivel. This arrangement permits normal excursions or surge of the ship due to wind, waves and currents without any danger of the ship overrunning any portion of the mooring system and prevents any mutual interference between the ship and the mooring system. As mentioned hereinabove the upper end 22 of the riser extends through the center of the mooring swivel and the riser is arranged in the center of the radiating anchor chains so that no mutual interference occurs between the riser and the anchor chains or between the riser and the ship.

The mooring swivel provided in this embodiment has an upper surface 24 substantially flush with the deck of the ship so that many essential services can be provided directly between the deck and the upper surface of the mooring swivel. A circular array of heavy duty tapered roller bearings 26 is provided between the upper flange surface 24 of the mooring swivel and the main body of the ship 10. This bearing 26 accommodates relative rotation between the mooring swivel and ship and carries the principle downward mooring load from the mooring swivel to the ship. The exterior portion of the mooring swivel then extends downwardly from the bearing 26 in a cylindrical portion 27 at least part way through the hull of the ship. The water line is normally in this cylindrical portion, its position, of course, varying with the quantity of oil in the ship's storage tanks. A pair of sliding bearing members 29 and 31 are mounted on the ship and mooring swivel respectively near the bottom of the ship for accommodating transverse loads between the mooring swivel and the ship which may be substantial when the forces acting on the ship are high and must be reacted by the mooring chains.

The inner surface 32 of the mooring swivel is in the general form of an open truncated cone having its smaller end near the upper surface 24 and flaring outwardly near the bottom of the ship. This provides clearance between the mooring swivel and the upper end 22 of the riser so that the pitch and roll of the ship can be accommodated without any impact between the riser and the swivel. As will become apparent hereinafter there is no direct connection between the riser and the swivel.

A plurality of hawse tubes 33 extend between the upper surface 24 of the swivel and the bottom of the swivel. These hawse tubes 33 are gently curved to gradually change the direction of the anchor chains 14 which are threaded therethrough as they extend between the bottom of the mooring swivel and the deck of the ship. A single hawse tube is provided for each of the eight anchor chains provided in this embodiment and these hawse tubes are substantially equally spaced around and outboard of the inner conical surface 32 of the mooring swivel. On the upper surface 24 of the mooring swivel adjacent the upper end of each of the hawse tubes 33 there is provided a chain stop 34 for individually locking each anchor chain 14 as is described in greater detail in the aforementioned copending patent application entitled, "Permanent Ship Mooring System."

As mentioned hereinabove a tower 23 is supported above the deck of the ship over the mooring swivel 12 and means are provided for accommodating relative motion between the tower and swivel. Thus, as provided in this embodiment an outer gimbal ring 36 is rotatably supported for rotation about an axis substantially normal to the swivel on the upper surface 24 of the swivel by a circular array of tapered roller bearings 37. The roller bearing 37 accommodates the weight of the tower and the tension load applied to the upper end 22 of the riser as hereinafter described in greater detail. The tower is prevented from rotating relative by the ship by a forked member 40 (also seen in FIG. 1, but omitted from FIG. 2 for clarity) having its bifurcated end attached to the outer gimbal ring 36 and its single end attached to the deck of the ship. This forked member thus prevents the gimbal ring 36 from rotating relative to the ship about a substantially vertical axis and thereby prevents the tower mounted within the gimbal ring from turning. Since the mooring swivel is separated from the ship and tower by bearings 26 and 37, respectively, it is free to rotate relative to both about a vertical axis.

A pair of opposed trunnions 38 (only one is seen in FIG. 2) on the outer gimbal ring 36 support an inner gimbal ring 39 which is therefore free to tilt about an axis extending along the length of the ship. A pair of trunnions 41 on the inner gimbal ring 39 are also connected to a spherical member 42 therewithin. This permits the spherical member to tilt about an axis athwart the ship. The spherical member 42 and the tower 23 which is connected thereto is therefore free to tilt on trunnions 38 and 41 about orthogonal axes and therefore in any direction relative to the deck of the ship. The weight of the tower and tension load on the upper end of the riser is transmitted through the spherical member 42 to the trunnions 41, thence to the inner gimbal ring 39 and the trunnions 38 which apply the load to the outer gimbal ring 36 mounted on the swivel plug 24 by the bearing 37. All of the loads are ultimately carried to the buoyant hull of the ship through the heavy bearing 26 supporting the swivel.

In order to maintain the gimbal mounted tower 23 in a substantially vertical orientation, four guying cables 43 are connected to the upper portion of the tower and extend outwardly therefrom to damping shock absorbers 44 near the edge of the ship. Each of the shock absorbers or dampers 44 can be fixed in position, if desired, to maintain the tower in a fixed orientation relative to the deck of the ship. In normal operation, however, the angular position of the tower follows that of the upper end of the riser and therefore the shock absorbers serve to limit the angular excursions that the tower can follow and also serve to inhibit rapid or oscillatory motions.

The tower 23 comprises a structural base 46 which is rigidly connected to the spherical member 42. Connected to the tower base 46 are a pair of side rails 47 which extend substantially vertically along the length of the tower to form the principal structure of the tower. Each of the side rails has a cross section substantially in the form of an I-beam as can be seen in the cutaway portion of FIG. 2. The side rails 47 are joined together at the apex of the tower to provide a load carrying point for applying a tension to the upper end of the riser.

A cagelike draw bar 48 is mounted with end portions fitted within the opposite sides between the flanges of the I-beam shaped side rails 47 of the tower. Bearing wheels 50 (FIG. 3) on the ends of the draw bar 48 engage the web and flanges of side rails 47 of the tower to permit vertical motion of the draw bar along the length of the tower. Roller chain sprockets 49 are mounted within each open side of each of the I-beam shaped side rails 47 and an endless roller chain 51 is provided between each of the four sets of sprockets 49. The roller chain 51 is connected to the draw bar 48 so that vertical motion of the draw bar along the side rails moves the chain which causes the sprockets 49 to rotate. The sprockets on opposite side rails of the tower are interlocked so that the draw bar is constrained to move along the length of the tower without cocking. In addition the sprockets 49 are connected to the impellers (not shown) of a conventional hydraulic damping system which circulates hydraulic fluid to damp out small amplitude and oscillatory vertical motions of the draw bar relative to the tower.

The draw bar 48 is rigidly connected to a pair of vertical structural members 52 extending above and below the draw bar on each side thereof. At their lower ends the structural members 52 are each connected to a ring 53 which supports the upper end 22 of the riser by means of a conventional swivel bearing 55 (FIG. 3). Thus the tension load on the upper end of the riser is applied thereto through the swivel bearing 55 between the upper riser end 22 and the ring 53 at the lower end of the structural members 52. The upper ends of the structural members 52 are connected by way of an open cage 54 to a clevis 56. The clevis is in turn supported by a hook 57 supported by a cable block 58. The load of the riser is transmitted through the vertical structural members from the ring 53 to the open cage 54 thence through the clevis 56 and the hook 57 to the cable block 58.

The tension load on the upper end of the riser is maintained constant by a conventional constant tension winch 59 on the deck of the ship. A pair of cables 61 extend from the winch 59 to the tower base and thence up along the side rails 47 of the tower by way of a series of pulleys 62. The tension cables 61 are led through the block 58 as many times as desired to obtain a given mechanical advantage. Thus by way of the cables 61 and the above-described structural linkages between the block 58 and the upper end 22 of the riser a constant tension is applied to the upper end of the riser. The nature of a constant tension winch is to apply a constant tension to the cable wound thereon irrespective of the cable position. Thus as the ship may rise or fall, for example, and the upper end 22 of the riser remains in a substantially fixed position, the draw bar 48 will ride up and down the side rails of the tower and more or less cable 61 is paid out or withdrawn as required by the constant tension winch 59. With this arrangement a constant tension is applied to the upper end of the riser throughout the extent of any excursion of the riser end along the length of the tower. Additional structural details of a tower and an alternative tower arrangement are contained in copending U.S. Pat. application Ser. No. 838,489, filed July 2, 1969 entitled, "Underwater Riser and Ship Connection," and Ser. No. 729,286, entitled "Marine Riser Structure" both by George W. Morgan, and assigned to North American Rockwell Corporation, assignee of this invention, the teachings of which are hereby incorporated by reference for full force and effect as if set forth in full herein.

A typical riser useful in practice of this invention is described in copending U. S. Pat. application, Ser. No. 721,014, entitled, "Multiconduit Underwater Line" by George W. Morgan. The riser described in this copending application has a plurality of fluid conduits extending along the length for communicating fluids between the upper and lower ends of the riser. In addition, electrical conductors are provided along the length of the riser for carrying power and electrical signals.

In the practice of this invention the riser is substantially fixed in position and the ship is free to pitch, roll, heave, and weathervane about the upper end of the riser and the riser and ship may surge together. As pointed out hereinabove the tower 23 rotates with the ship and the substantially fixed upper end of the riser is connected to the tower by way of a swivel bearing. In addition to this mechanical connection, electrical and fluid connections need be made to the upper end of the riser. Toward this end a conventional electrical swivel 63 having slip rings or the like, is mounted on the riser supporting ring 53. The electrical swivel is electrically connected to the conductors (not shown) of the riser. Flexible electrical cables 64 are also provided between the fixed portion of the electrical swivel 63 and the deck of the ship 10 for conducting power and electrical signals therebetween.

A conventional fluid swivel 66 is mounted above the electrical swivel 63 and in fluid communication with the conduits (not shown) of the riser. A typical fluid swivel useful in practice of this invention is described in copending U. S. Pat. application Ser. No. 736,398, entitled, "Multiple Pipeline Swivel Connector" by Eugene J. Camilla, assigned to North American Rockwell Corporation, assignee of this invention, and which is hereby incorporated by reference for full force and effect as if set forth in full herein. Fluid connections are made from the several manifolds of the fluid swivel 66 to conven-

67 or the pipes thereto are mechanically connected to the draw bar 48 so that they are constrained to move up and down along the length of the tower with motion of the riser head along the tower. Another complementary set of swivel joints 68 are mounted on the base 46 of the tower and therefore do not move with the riser head. A set of parallel rigid pipes 69 is connected to the upper swivel joints 67 and a similar set of parallel rigid pipes is connected to the lower swivel joints 68. The upper set of pipes 69 is connected to the lower set of pipes 71 by a third set of conventional swivel joints 72. The axes of motion of the several swivel joints in the sets 67, 68 and 72 are all parallel so that the sets of pipes 69 and 71 freely articulate as the upper end of the riser moves along the length of the tower. The articulated piping between the riser head moving along the length of the tower and the tower base provides for a great range of motion of the riser head without breaking fluid communication.

At the tower base the only motion encountered by the fluid lines is the tilt of the tower relative to the deck of the ship in two directions and this motion is small enough that fluid connection between the lower swivel joint 68 and the balance of the ship is made by conventional flexible tubing 73.

As the ship pitches or rolls the substantially fixed upper end 22 of the riser causes the tower 23 to tilt relative to the ship. In order to minimize the stresses on the riser at the location of the tower gimbal mounts, i.e., the spherical member 42, a riser guide or support tube 74 is attached to the spherical member 42 and extends downwardly therefrom substantially to the lower end of the mooring swivel 12. Thus both the guide tube 74 and the tower 23 are rigidly secured to the spherical member within the gimbal mounting, that is, the tower and guide tube are essentially a single rigid member pivotally mounted near its middle. Transverse loads between the riser and ship are coupled therebetween at the lower end of the guide tube, at the spherical member, and at the upper end of the riser adjacent the draw bar 48. By so distributing the loads extreme bending moments on the riser at the gimbal support are avoided.

As the ship heaves, the riser must travel along the length of the guide tube 74 and therefore as illustrated in FIGS. 4 and 5 contoured rubber rollers 76 and 77 are rotatably mounted transverse to the tube axis at the upper and lower ends respectively of the guide tube. The guide rollers 76 and 77, which may be segmented if desired to minimize friction, are contoured so as to engage the periphery of the cylindrical riser and thereby permit free relative motion of the riser along the length of the tube while providing support. Transverse loads by the riser on the guide tube 74 are transmitted thereto by way of the rollers 76 and 77.

It will also be apparent that if the guide tube 74 is fixed relative to the tower that the riser must rotate about an axis along the length of the guide tube. The contoured rubber rollers 76 and 77 bearing on the riser effectively prevent rotation between the riser and the guide tube 74. Therefore a pair of bearings 78 are provided between the guide tube 74 and the spherical member 42 so that the entire guide tube can rotate about its axis, relative to the spherical member 42 and tower and yet transmit a substantial transverse load to the spherical member. Additional structural details of the guide tube 74 and its mounting are contained in copending U. S. Pat. application, Ser. No. 838,513 entitled, "Riser Support Structure" by John M. Deslierres, and assigned to North American Rockwell Corporation, assignee of this invention, the teachings of which are hereby incorporated by reference for full force and effect as if set forth in full herein.

In the normal course of operation of a ship and riser system as provided in practice of the principles of this invention the ship may pitch, roll, heave, yaw and drift or surge relative to the riser base at the sea floor. The mechanisms hereinabove described and illustrated schematically in FIG. 3 accommodate all of these motions without applying undue stresses

Thus, for example, as the ship heaves the riser moves relative to the ship along the length of the guide tube 74 extending through the mooring swivel 12. Rollers 76, 77 in the guide tube roll along the length of the riser to permit free relative motion in a substantially vertical direction. At the same time the uppermost end of the riser is connected to the draw bar 48 which is free to move along the length of the tower 23 above the deck of the ship on rollers 50. The draw bar and hence the upper end of the riser is supported from the top of the tower so that a constant tension is applied on the upper end of the riser by way of the cables 61 and the constant tension winch 59. Vertical motion of the electrical connections is accommodated by the slack electric cables running to the upper end of the swivel from the deck of the ship. Similarly, vertical motion of the fluid connections to the riser is accommodated by articulated piping between the riser head and the base of the tower.

Pitch or roll of the ship changes the angular relation between the riser and the ship and this is also accommodated by the mechanisms hereinabove described. As the riser tips relative to the ship (or vice versa) pivoting effectively occurs at the gimballed mounting of the tower base about the gimbal 41 and the transverse gimbal 38 (FIG. 2 and indicated schematically by the curved arrow at the top of the tower). As the riser tilts so does the tower to which it is attached with the tilting occurring in the aforementioned gimbals. Moments are applied by the riser on the guide tube 74 and on the tower to cause tilting thereof and the extent of tilt is limited by guy cables leading to a tower restraining and damping system (not shown in FIG. 3). Tilt of the riser, and hence tower, is accommodated in the fluid connections by small motions of the articulated piping and the flexible tubing extending between the tower base and the ship.

Yawing or weathervaning of the ship relative to the riser may also occur. The riser is essentially fixed in position at its upper end relative to the ship mooring system which comprises the mooring swivel pivotably mounted within the vertical aperture in the ship and the plurality of radially extending mooring chains for holding the ship in a reasonably constant position. Thus the mooring swivel 12 is substantially fixed in attitude relative to the ocean bottom by the mooring chains and the riser is substantially fixed in attitude by its inherent stiffness. Weathervaning of the ship relative to the mooring system is provided by the swivel plug which is mounted on bearings 26 to permit relative rotation. Weathervaning of the tower relative to the swivel is accommodated by bearings 37. Weathervaning of the ship relative to the riser is provided by supporting the upper end of the riser by a swivel bearing 55 which permits the ship and tower to rotate about the riser. In addition, bearing support 78 for the guide tube 74 permits it to rotate with the riser relative to the ship so that no substantial torsion loads are applied to the riser by the ship. Rotation of the electrical line of the riser is accommodated by an electrical swivel at the upper end of the riser and a fluid swivel in the same general location permits relative rotation of the fluid conduits of the riser relative to the ship.

Although the individual motions of heave, pitch, roll, yaw and surge have been described it will be apparent that these may all occur simultaneously in a given situation; thus, for example, as the ship drifts or surges off of a vertical position directly above the riser base within the limits permitted by the mooring system, the riser will appear to tilt relative to the ship and also be effectively shorter. At the same time roll, pitch and heave of the ship due to wave action, are dynamically accommodated by the mechanisms hereinabove described. During this period the ship may very well weathervane in response to tidal currents so that all of the above-described motions are occurring simultaneously.

It will be apparent that many modifications and variations of the present invention are possible in light of the above teachings. Thus, for example, many variations can be made in the detailed structures providing the several degrees of freedom between the ship and riser while still maintaining constant tension on the riser plus fluid and electrical communication between the ship and the riser during the complex motions occurring.

What is claimed is:

1. A sea going storage tanker comprising:
a streamlined hull:
means within said hull for storing substantial quantities of fluid;
said hull having a vertical aperture through said hull at a distance from the bow of no more than twenty percent of the bow to stern length of said hull;
a mooring plug in said aperture;
means for anchoring said mooring plug to the sea floor;
bearing means between said mooring plug and said hull for permitting relative rotation therebetween about a substantially vertical axis;
said mooring plug having a substantially vertical passage;
a substantially vertically disposed tower mounted over the passage in said mooring plug and connected to said hull for minimizing rotation between said tower and said hull about a substantially vertical axis;
support means for said tower for permitting limited rotation of said tower relative to said hull about at least two axes in a substantially horizontal plane,
means on said tower for connection to an upper end of an underwater riser, and means for connection further comprising:
means for applying a substantially constant tension to the end of the riser during relative translation of the riser end along the height of the tower;
a fluid manifold mounted for translation along the length of said tower and restricted from rotation relative to said tower about an axis along the length thereof, said fluid manifold being connected to said riser for transfer of fluids therebetween; and
an articulated fluid conduit between said fluid manifold and the tower.

2. A tanker as defined in claim 1 wherein said support means for mounting said tower comprises:
a tower base;
first and second orthogonally arranged gimbal means on said mooring plug and supporting the lower end of said tower for limited rotation thereof about at least two axes in a horizontal plane;
a plurality of guy cables connected to the upper end of said tower; and
constant tension means interconnecting each of said guy cables and said hull for permitting limited motion of the upper end of said tower relative to said hull.

3. A combination comprising:
a floating structure at the surface of the sea;
an elongated multiple conduit riser having a lower end connected to the sea floor;
means interconnecting the floating structure and the upper end of said riser, said means comprising means connected to the upper end of said riser for maintaining a substantially constant tension on said riser despite relative motion between said surface structure and the sea floor;
means between the ends of said riser for conveying fluids between the interior of each of the multiple conduits and said floating structure comprising:
a fluid manifold surrounding a portion of the length of said riser and in fluid communication with a conduit thereof, and
means for accommodating relative rotation between said manifold and said conduit about an axis substantially coincident with the axis of said riser so that said surface structure may rotate about said riser; and
means at a location substantially coincident with the upper end of said riser for mooring the floating structure to the sea floor for limiting lateral translation thereof comprising:
a mooring plug including a circular portion,
means for anchoring the mooring plug to the sea floor, and

bearing means interconnecting the circular portion of said mooring plug and said floating structure for permitting relative rotation therebetween for minimizing relative rotation between said riser and said mooring plug while permitting relative rotation between said floating structure and said riser.

4. A combination as defined in claim 3 wherein said means interconnecting the floating structure and the riser comprises:

a tower mounted on said floating structure over said mooring plug to the floating structure so as to prevent relative rotation therebetween about an approximately vertical axis;

means for mounting said tower on said floating structure for permitting limited rotation therebetween about at least a pair of axes in a substantially horizontal plane;

said tower supporting at least a portion of said means for applying constant tension to said riser; and

means on said tower for fluidly interconnecting the fluid manifold on said conduit and a point adjacent the base of said tower.