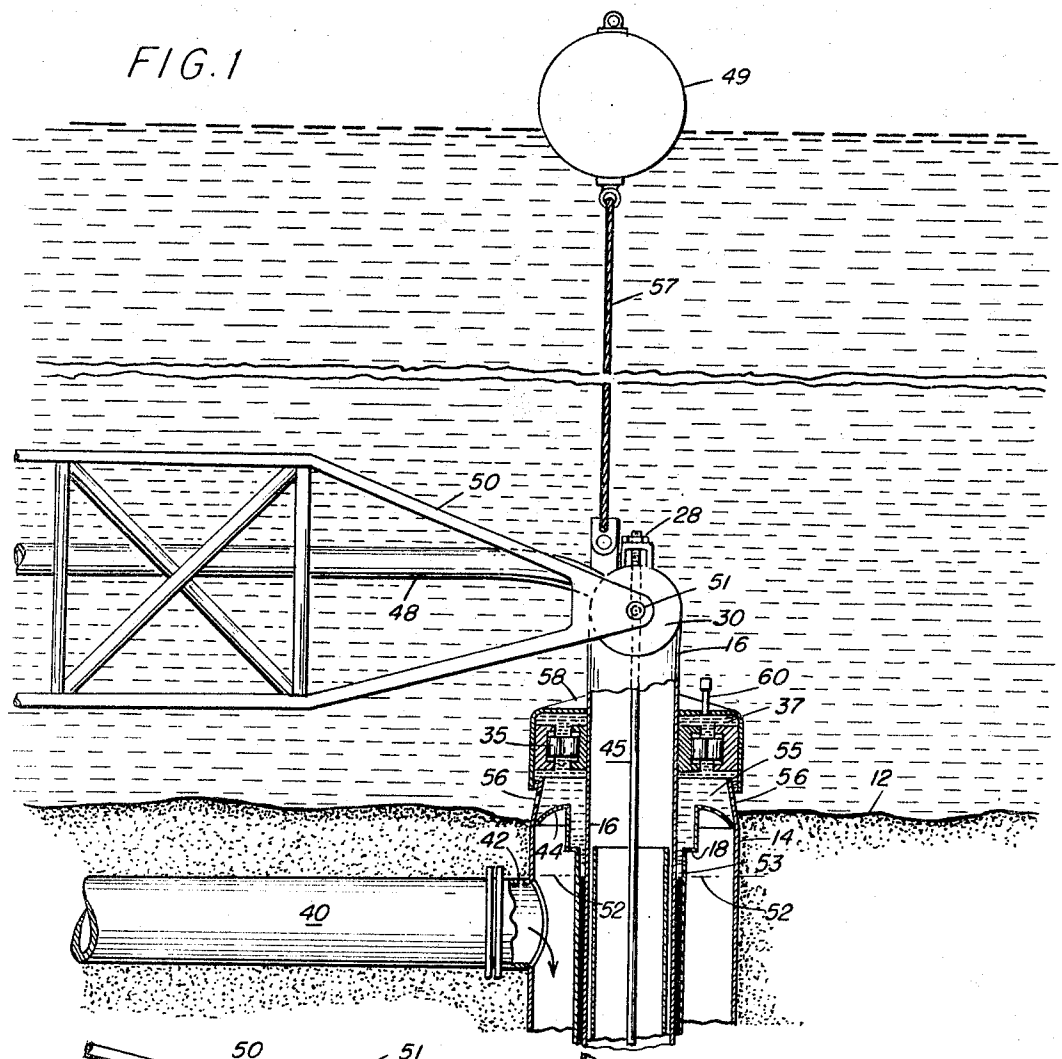
March 28, 1967 E. V. BERGSTROM 3,311,142

TANKSHIP MOORING AND LOADING SYSTEM

Filed April 30, 1964 5 Sheets-Sheet 1

FIG. 1



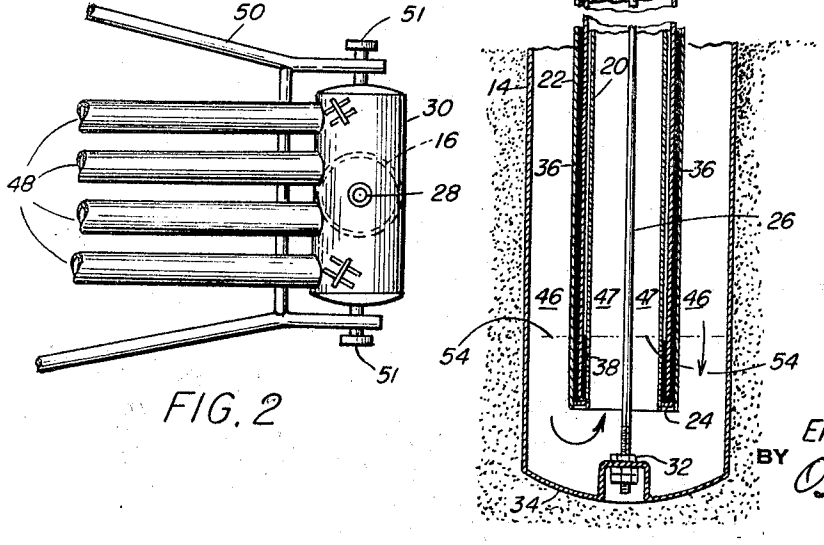




FIG. 2

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TANKSHIP MOORING AND LOADING SYSTEM

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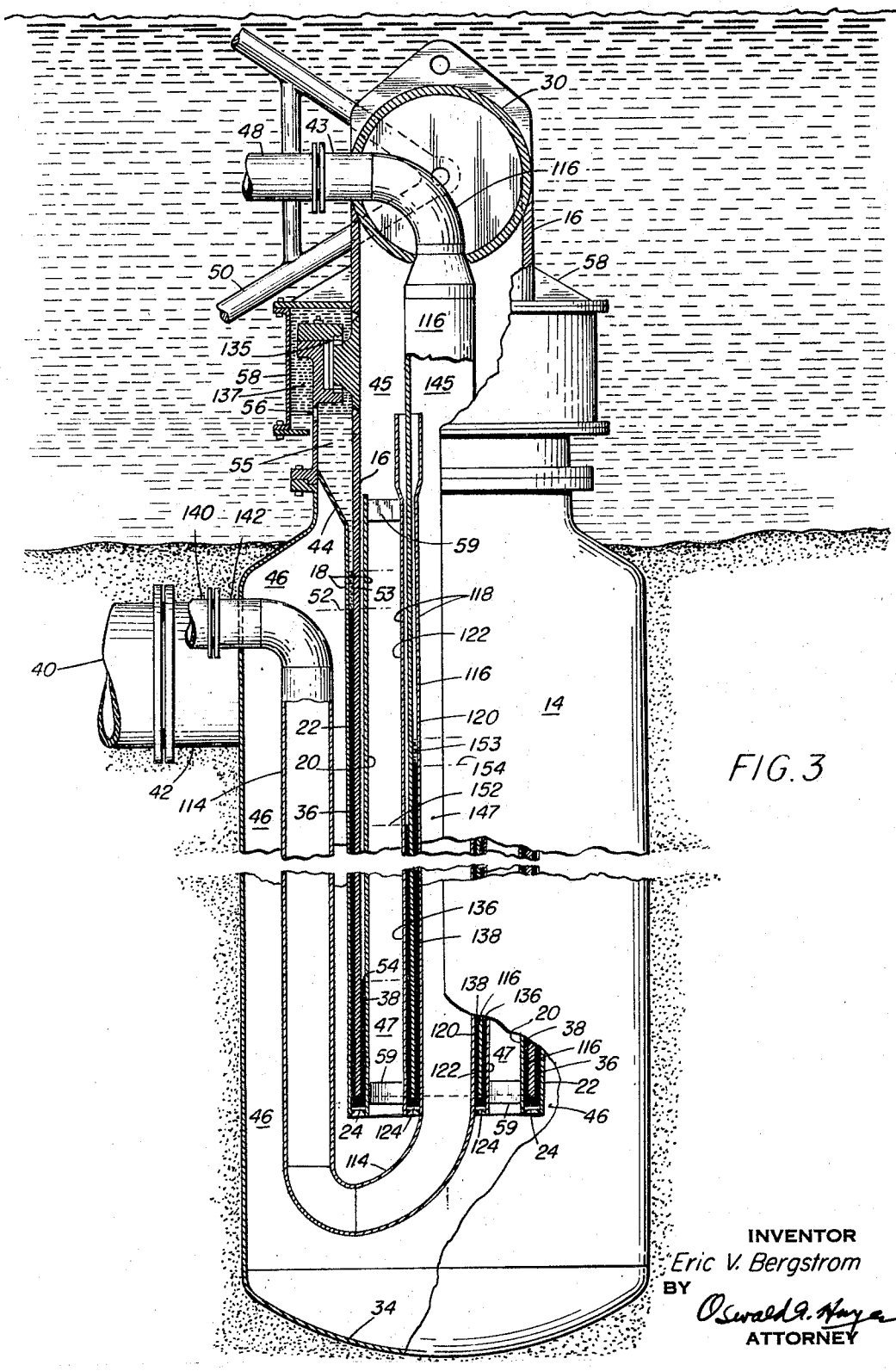



FIG. 3

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TANKSHIP MOORING AND LOADING SYSTEM

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FIG. 5

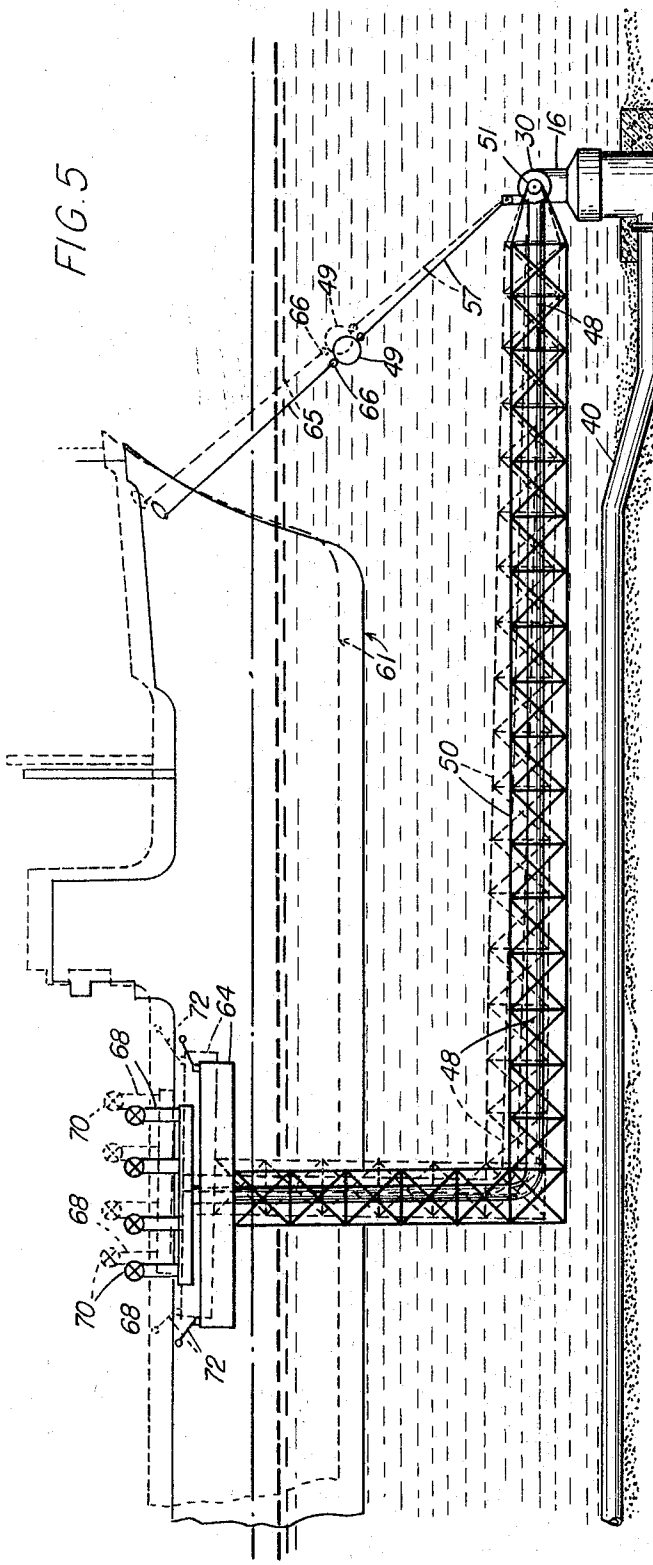
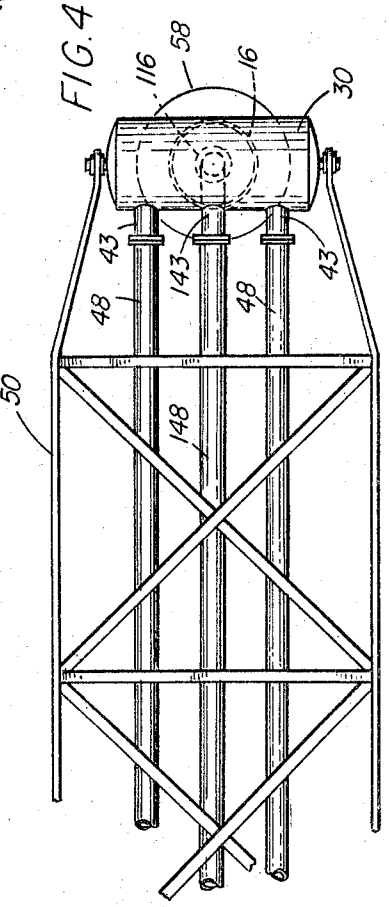



FIG. 4




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TANKSHIP MOORING AND LOADING SYSTEM

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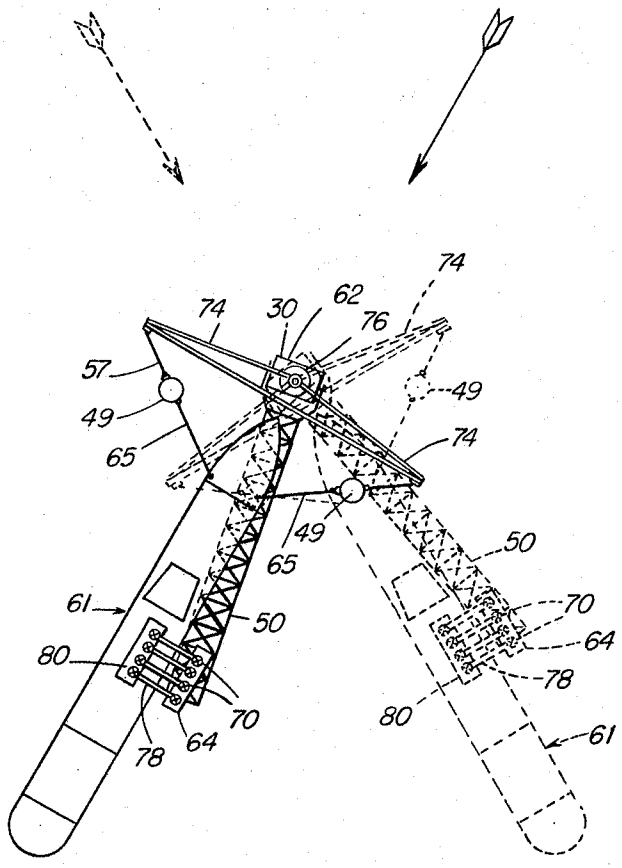



FIG. 6

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TANKSHIP MOORING AND LOADING SYSTEM

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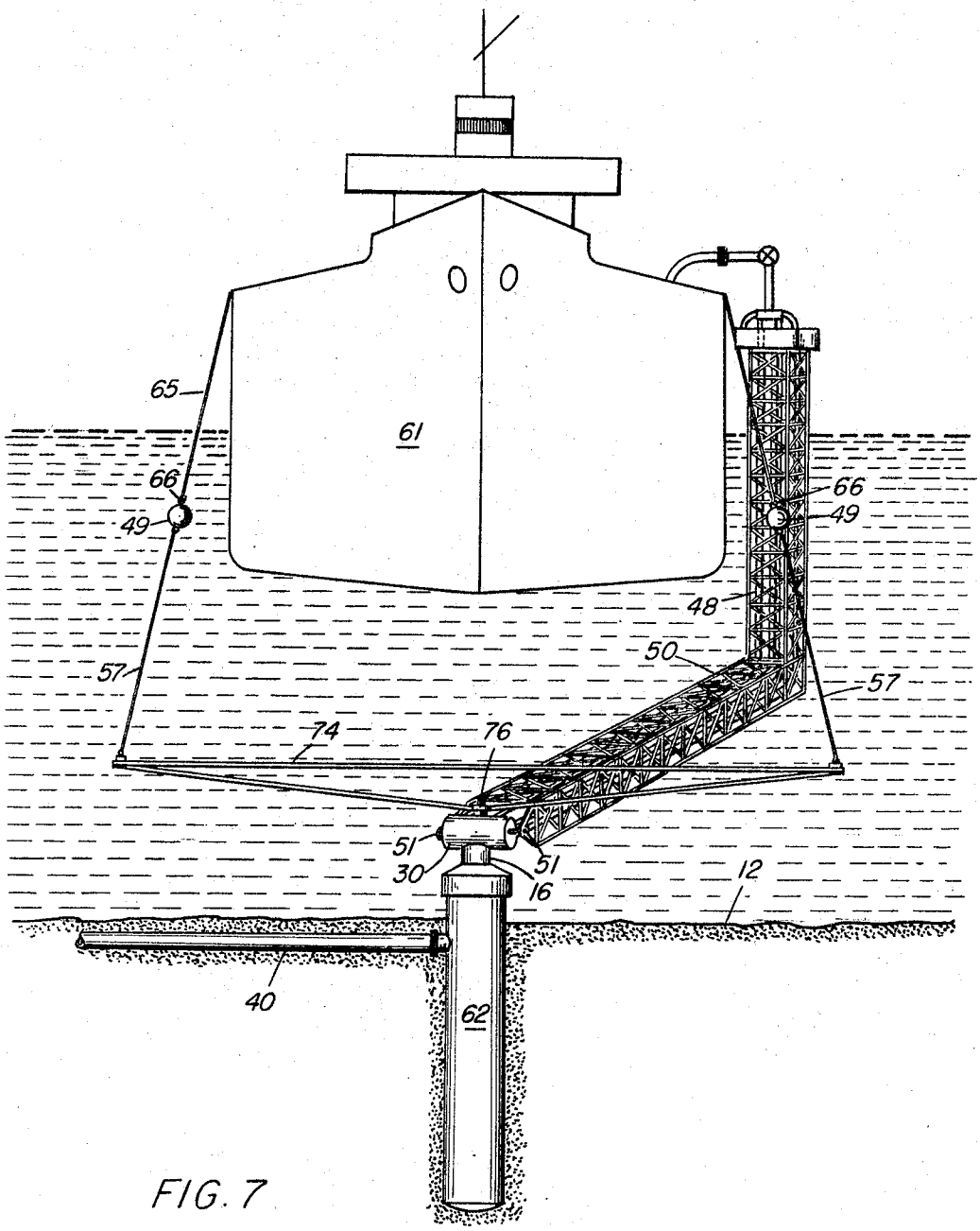



FIG. 7

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United States Patent Office 3,311,142 Patented Mar. 28, 1967



3,311,142

# TANKSHIP MOORING AND LOADING SYSTEM

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Filed Apr. 30, 1964, Ser. No. 363,844
6 Claims. (Cl. 141—388)

This invention relates to an offshore tankship mooring and loading system whereby loading and unloading of liquid material, particularly petroleum products, crude oil and chemicals, is made possible in areas of inadequate docking facilities. More particularly, the invention relates to the improvement of such systems attainable by the utilization of a novel underwater swivel joint comprising a mercury seal, which joint connects a fixed submarine line and a rotatable loading line.

Several systems are known in the art for the loading and unloading of seagoing vessels. A suitable system provides means for mooring and loading a vessel while essentially unaffected by or adaptable to a continuous shifting of the vessel due to variations in the tide, loading, wind or wave action. In the loading of liquids such as petroleum products, chemicals and the like, provision must also be made for a conduit between the vessel storage chambers and onshore storage facilities.

Suitable systems known in the art for the loading of liquids in tankers and the like include permanent piers, submarine anchorages, floating terminals and rotating booms. Customarily tankers are loaded at permanent piers in protected waters or harbors, whereby the ship is moored to a pier running parallel thereto and liquid connection is provided by flexible lines. The pier restrains lateral movement of the ship and the flexible lines adjust to vertical movement due to tidal and loading variation without undue strain on the vessel connections. Piers, however, are not available or suitable in all areas, and, consequently, in such areas mooring and loading of tankers must be accomplished without the protection of permanent fixed piers in harbors or other protected waters.

The customary alternative where permanent piers are unavailable is offshore mooring, whereby a flexible coupling is provided for the transfer of liquid between a fixed submarine line running from shore storage and a moored continuously shifting tanker. Common methods of offshore mooring and loading include submarine anchorages, floating terminals and rotating booms.

Submarine anchorages, see U.S. Patents 2,648,201 and 2,955,626, comprise a fixed submarine line running to an anchorage on seabottom, coupled to flexible loading hoses running to a tanker manifold. The hoses are long and heavy; and, due to a weight limitation of the tanker's gear, practically are limited in size and capacity. Moreover, bow loading is a virtual necessity, since the tanker is moored at its bow to allow the tanker to face the wind. Few ships are equipped with bow manifolds. To load via amidships manifolds of a tanker moored at the bow requires running a long hose from bow to midship or a floating hose alongside, and has been found undesirable.

Floating terminals, see U.S. Patents 2,894,268 and 3,074,082, comprise a fixed submarine line coupled to a flexible vertical line running to an anchored, floating terminal. A tanker is moored by bow to the terminal, and hoses are run to its manifolds. As with the submarine anchorage system, preferably the floating terminal hoses are connected to bow manifolds. But, as mentioned above, few ships have such facilities. Moreover, the floating terminal is subject to ramming by the moored ship, which possibility presents a potential hazard when such a system is utilized.

A recently developed system, a fixed caisson-rotating boom combination effectively avoids many of the impracticalities and shortcomings inherent to prior offshore mooring systems, see U.S. Patent 3,093,167. Such a system comprises a fixed submarine line running to a large caisson, anchored to the sea floor by pilings, supporting a rigid platform protected from ramming by fendering tubes and a box girder. The submarine line extends to a fixed vertical feed line running to a rotating joint on the platform above water. The bow of a tanker is attached thereto. The rigid platform has attached to it a rotatable turntable combined with a loading boom, comprising liquid conduits, extending largely underwater to a loading platform at midship. The loading boom is relatively rigid. Thus, connections to the amidships manifold may readily be made from the adjacent loading platform, which has provision automatically to adjust by free rotation to a composite vector of tide, wind, sea and current as well as to compensate by variable buoyancy to tide changes and for the changing buoyancy of the tanker during loading. Essentially, the fixed caisson-rotating boom offshore mooring system, by providing amidships loading and by shifting with the loading vessel, eliminates the need for long and heavy hoses which practic ally limited capacity and operability of early offshore mooring systems. This improved system, however, is exceedingly large and expensive and presents a significant hazard to damage by ramming of its sizable above-water caisson, notwithstanding its fendering tubes. Repairs to a damaged boom, turntable or feed line could be effected only at great expense and inconvenience.



It is a major object of the present invention to provide an offshore mooring system unencumbered by the above disadvantages of the present systems.

To provide an offshore mooring system, wherein the hazard of damage by ramming is obviated substantially by placement of its major components under water below the ship's hull, is an objective of the present invention.

It is a further object to provide a loading platform capable of shifting with the moored ship in order that undue stress on the ship's lines, joints and equipment may be reduced significantly.

A primary object and embodiment of the present invention is the provision of an offshore mooring system, wherein a tanker may be bow-moored, free to swing about due to changes in tides, current or wind without danger of ramming said mooring system, and said tanker may be loaded or unloaded from a loading platform, free to swing about with said tanker at midship as well as free to rise or fall with said tanker, to compensate in part for vertical movement thereof as it is loaded or as the tide changes, with the result that a minor load and strain is put on the lines, joints and equipment of said tanker during loading.

A further object and result is to provide such improved mooring system with a trouble-free underwater swivel joint, comprising a mercury seal, whereby maintenance is substantially eliminated.

Briefly the present invention in essence comprises an underwater swivel joint providing a conduit, between a fixed submarine line and a rotatable loading line, for transfer of liquids between said submarine line and said rotatable loading line, which joint comprises a mercury seal, between said liquid and seawater, of a height sufficient to balance a pressure differential between said liquid and said seawater. Beneficially said swivel joint includes a further seal between said mercury seal and seawater, of a material immiscible to both and having a specific gravity intermediate said mercury and said seawater, which seal prevents electrolytic corrosion of metal parts of said joint.

Additionally, the present invention comprises an offshore mooring and ship loading system and method in-

cluding essentially the above swivel joint. Said system is a combination of a submarine line extending from shore facilities to the above swivel joint, said swivel joint located on the sea bottom with a conduit rotating about a vertical axis, a horizontally rotatable, vertically, pivoted, submerged boom attached to said rotating conduit, which boom supports a flexible loading line, both swivel joint and boom being submerged to a depth sufficient to obviate ramming by the moored ship, a loading platform above water at the outer end of said boom and support therefor extending upwardly to the platform, and connections on the loading platform between the loading line extending from the swivel joint to the platform and hoses connected to the storage chambers of the moored ship. Preferably the boom is of buoyancy sufficient to maintain the loading platform above water and to minimize the strain of the system upon the swivel joint.

The advantages of the present mooring and ship loading system will be apparent to those skilled in the art from the above brief description and the following detailed description of preferred embodiments thereof. Significantly, only the loading platform is above water and subject to ramming. But the loading platform is moored to the tanker and shifts in part therewith and provision can readily be made to avoid ramming thereby. Significant also is the improvement of the present system whereby the platform, on a horizontally rotatable, vertically pivoted boom, is able to rotate with the wind or current about the ship's mooring point and move up and down with the moored ship. These advantages are made possible essentially by the use of an underwater swivel joint, virtually maintenance- and trouble-free, comprising a mercury seal.

The principles and advantages of the present invention will be more fully understood by a consideration of preferred embodiments shown in the attached drawings, wherein:

FIGURE 1 is a detailed cutaway and cross-sectional view of a preferred embodiment of the essential component of the present invention, a mercury-seal swivel joint.

FIGURE 2 is a top view of the embodiment of FIGURE 1 at the axial end of the rotating boom showing a preferred connection of plural loading lines to the rotating conduit of the swivel joint.

FIGURE 3 is a detailed cutaway and cross-sectional view of an alternative embodiment of the present invention wherein two mercury-seal swivel joints allow simultaneous transfer of two liquids between a moored tanker and shore storage facilities.

FIGURE 4 is a top view of the embodiment of FIGURE 3 at the axial end of the rotating boom showing a connection of plural loading lines allowing simultaneous transfer of two liquids.

FIGURE 5 is a diagrammatic illustration of the components of a preferred offshore mooring ship loading system in operation, herein referred to as a single point mooring system.

FIGURE 6 is a top view of the preferred system of the present invention in operation, combined with an alternate mooring scheme employing a mooring yoke, herein referred to as a single point mooring system with yoke.

FIGURE 7 is a view from the bow of a tanker moored to a single point mooring system with yoke and being loaded from the port side according to the method of the present invention.

FIGURE 1 in elevation and in detail illustrates by longitudinal cross-section of the lower part a preferred embodiment of a mercury seal swivel joint, a major component of the system of the present invention. The swivel joint is submerged at a depth sufficient to prevent contact with loading vessels and preferably is at sea bottom 12, with a major portion thereof buried in the sea floor or alternatively within a concrete foundation not shown (see



FIGURE 5). The swivel joint comprises two vertical concentric cylindrical conduits, a fixed conduit 14 and a movable conduit 16. Movable conduit 16 is enclosed within sheath 18, which comprises an inner cylinder 20 and an outer cylinder 22, both cylinders being concentric and adjacent, both encasing movable conduit 16. The bottom annulus of cylindical sheath 18 is closed by bottom ring 24. A tie rod 26 prevents vertical motion of movable conduit 16 relative to fixed conduit 14, but permits rotating motion of movable conduit 16. Tie rod 26 is joined by swivel 28 on header 30 welded to the top of movable conduit 16, and by swivel 32 on bottom cover 34 of fixed conduit 14.

Thus, movable conduit 16 is fixed and prevented from vertical motion by tie rod 26, is encased within a double concentric-cylinder sheath 18 and is freely rotatable within fixed conduit 14. Movable conduit 16 is retained within fixed conduit 14 by bearings 35 therebetween in oil bath 37, which bearings also prevent horizontal motion of conduit 16 while permitting rotation thereof. Mercury or another heavy fluid for use as a suitable seal is contained within sheath 18 and forms two seal annular columns, an outer annular column 36, bounded by the inner surface of outer cylinder 22 and the outer surface of movable conduit 16, an an inner annular column 38, bounded by the inner surface of movable conduit 16, and the outer surface of inner cylinder 20.

In the operation of the swivel joint above described a liquid from submarine line 40 enters fixed conduit 14 near its top by side inlet flange 42. The liquid is prevented from passing upwardly by top ring 44 and passes downwardly in the annulus 46 bounded by the inner surface of fixed conduit 14 and the outer surface of outer cylinder 22. Upon reaching the bottom cover 34 the liquid moves radially inwardly towards the central part of fixed conduit 14 and passes upwardly in the cylindrical zone 47 bounded by the inner surface of inner cylinder 20 of sheath 18. The liquid travels the length of sheath 18 and passes out the top thereof and enters the cylindrical channel 45 bounded by the inner surface of movable conduit 16, passes through movable conduit 16 into header 30, and exits via at least one flexible line 48 supported by boom 50. The details of header 30 and flexible lines 48 may be more readily understood by reference to FIGURE 2, a top view thereof. It can be seen that header 30 is a horizontal pipe affixed at right angles to vertical movable conduit 16 and having affixed thereto flexible lines 48 which are supported by the cross arms of boom 50 pivoted on header 30 by pivots 51.

Consequently, in essence the swivel joint provides means of a sealed fluid connection between a fixed submarine line 40 and flexible lines 48, rotatable about the common vertical axis of movable conduit 16 and fixed conduit 14 and pivoted about a horizontal axis coincident with that of header 30. The location of the swivel joint is indicated at sea level by buoy 49 at the end of float line 57. Accordingly, a tanker may be moored by securing a line to buoy 49.

The liquid being transported through the swivel joint, as hereinabove mentioned, is sealed from seawater in which the joint is submerged by a suitable heavy liquid, preferably mercury. The seal is self-adjustable to variations in the pressure difference between the transported liquid and the seawater. In a manner like a U-tube, the pressure difference is reflected in a difference in height of outer annular column 36 and inner annular column 38, connected at their bases and adjustable to the varying pressure difference. When mercury is used as the sealant, the instantaneous pressure difference is equivalent to the height of mercury between the top of outer annular column 36 at 52 and the top of inner annular column 38 at 54. Thus the seal may be maintained over a wide range of liquid pressure which determines a minimum height of annular columns 36 and 38, that is definitive of the height of the swivel joint.

When mercury is used as the seal liquid of necessity a non-electrolytic water-immiscible seal is provided between the mercury and seawater to prevent electrolytic corrosion of metal parts of the swivel joint. Such a non-electrolytic seal **53** is maintained above outer annular column **36** of the mercury seal in sheath **18**. The fluid is non-electrolytic, water-immiscible and has a specific gravity intermediate seawater, (1.025) and mercury (13.546). A preferred material for the seal **53** is fluorotrichloromethane (1.494) although other chlorinated hydrocarbons of the required physical characteristics are available and suitable. Above the non-electrolytic seal **53** is seawater in surge zone **55** free to move in and out of the system through slots **56** as the mercury seal moves up and down due to pressure changes of the transported liquid. Above the seawater in surge zone **55** is an oil bath **37**, of a lubricating mineral oil, enclosed by shroud **58** which is provided with an oil fill connection **60**.

It should be noted that the present system and method eliminate one of the hazards of tanker loading: the rupture of loading hose due to hydraulic shock when valves on the tanker are to rapidly close. By the use of a mercury-seal swivel joint herein, hydraulic shock is relieved by a rise in the outer annular mercury column. With this in mind, a surge zone **55** of expanded diameter is provided at the top of the column to contain and to prevent blowout by an excessive and sudden rise of the mercury column.

Specifications of a preferred swivel joint as hereinabove described, suitable for the loading of typical ocean tankers in an offshort mooring and loading system of the present invention are shown in Table I:

TABLE I

| | Preferred | Range |
|---|---|---|
| Fluid capacity, g.p.m. | 36,000 | 15,000–50,000 |
| Fixed conduit dia., ft. | 8 | 5–12 |
| Movable conduit dia., ft. | 3.5 | 2–5 |
| Sheath clearance, in. | .25 | .125–.75 |
| Height of mercury seal, ft. | 48 | 25–60 |
| Mean depth at sea bottom, ft. | 90 | 80–125 |

Within the ranges shown in Table I it is preferred that the movable conduit diameter be from about ¼ to about ¾ the diameter of the fixed conduit.

Referring now to FIGURES 3 and 4, there are shown a cutaway side view and top view respectively of an alternative embodiment of the present invention, a multiple stream swivel joint adapted for service where streams of two or more liquids desirably are to be transferred simultaneously between a moored tanker and shore storage facilities. Such device comprises elements identical in function with those of the single stream swivel joint hereinabove disclosed, and accordingly components of identical function will be numbered identically for both the single stream device and the alternative multiple stream device.

Elements of the major stream conduit of the multiple stream swivel joint are analogous to the elements of the single stream conduit, to wit: fixed conduit **14**, movable conduit **16**, sheath **18** (comprising inner cylinder **20**, outer cylinder **22**, bottom ring **24**, and top ring **44**), header **30**, bottom cover **34**, outer mercury annular column **36**, and inner mercury annular column **38**. Movable conduit **16** is retained within fixed conduit **14** by radial and thrust bearing **135** in oil bath **137**, which bearing prevents horizontal and vertical motion of condit **16** while permitting rotation thereof about a substantially vertical axis, coincident substantially with the axis of fixed conduit **14**.

Elements of the secondary stream conduit are similar to and largely within the concentric with the major stream conduit above described. A secondary inlet **142** is provided near the top of fixed conduit **14**. A fixed secondary conduit **114** leads from secondary inlet **142** downwardly and inwardly to inner cylinder **120** of secondary sheath **118**. Secondary sheath **118** comprises inner cylinder **120**, outer cylinder **122** and bottom ring **124**, and is fixed in a vertical position by welded supports **59** which secure secondary sheath **118** within sheath **18**. A secondary movable conduit **116** is encased within double concentric-cylinder secondary sheath **118**, is affixed to movable conduit **16** at the top thereof, and is connected with secondary inlet **143** near the junction of movable conduit **16** and header **30**. Thus, secondary movable conduit **116** is concentric with and affixed to movable conduit **16**, and both movable conduits are jointly rotatable about a common, substantially vertical axis.

In operation of an offshore mooring system, it may be desirable to transfer simultaneously plural streams between a moored tanker and shore storage facilities. Thus, for example, a crude oil may be pumped from shore storage to the moored tanker while ballast water is being pumped from the tanker to shore. Alternatively, two different streams, such as crude oil and bunker oil may be pumped simultaneously from shore to tanker or from tanker to shore. The above alternative procedures may be achieved according to the present invention by the use of the multiple stream swivel joint, shown in FIGURES 3 and 4, whereby a major stream, such as crude oil, may be transferred from shore to tanker while a secondary stream, such as ballast water, is transferred from tanker to shore. The major stream is transferred through the major stream conduit while the secondary stream is transferred through the secondary stream conduit, located within and largely concentric with the major stream conduit.

In a typical operation of the major stream conduit above described, a crude oil being transferred from shore storage facilities to a moored tanker via submarine line **40** enters fixed conduit **14** near its top by side inlet flange **42**. The crude oil is prevented from flowing upwardly by top ring **44** and passes downwardly in the annulus **46** bounded by the inner surface of fixed conduit **14** and the outer surface of outer cylinder **22**. Upon reaching the bottom cover **34**, the crude oil moves radially inwardly toward the central part of fixed conduit **14** and passes upwardly in the annular zone **47** bounded by the inner surface of inner cylinder **20** of sheath **18** and the outer surface of outer cylinder **122** of secondary sheath **118**. The crude oil passes the length of annular zone **47** and enters the annular channel **45** defined by the inner surface of movable conduit **116** and conduit **16**. The crude oil enters header **30** and passes out into flexible lines **48** through outlets **43** on header **30**. The major stream flow above described may be that of crude oil being loaded on a moored tanker from shore storage facilities. Conversely, if it is desired to unload and to transfer a major stream from tanker to shore, the sequential flow, of course, would be the reverse of the above.

Likewise, a secondary stream may be transferred simultaneously with a major stream in either direction through the multiple stream swivel joint between a moored tanker and shore storage facilities. For example, a secondary stream of ballast water may be transferred from the moored tanker to shore while a major stream of crude oil is being pumped in the reverse direction as above described.

Accordingly, ballast water coming from a tanker not shown via loading line **148** supported on boom **50** enters secondary inlet **143** and passes downwardly in cylindrical region **145** defined by secondary movable conduit **116**. The ballast water continues downwardly through cylindrical channel **147**, defined by the inner surface of inner cylinder **120** of secondary sheath **118**, into secondary fixed conduit **114**, whereupon the ballast water passes upwardly through conduit **114** and exits from the swivel joint by outlet **142** into secondary submarine line **140**.

As in the single stream swivel joint, a mercury seal is provided between the major stream liquid and seawater for a multiple stream swivel joint, and in addition a sec-

ondary mercury seal is provided between the major stream liquid and secondary stream liquid. Referring again to FIGURE 3, there is seen a mercury seal, self-adjustable to variations in the pressure difference between the crude oil and the seawater.

In a manner like a U-tube, the pressure difference is reflected in a difference in height of outer annular column **36** and inner annular column **38**, connected at their bases and adjustable to the varying pressure difference. Mercury preferably is used as the sealant; thus the instantaneous pressure difference between the crude oil and the seawater is equivalent to the height of mercury between the top of the outer annular column **36** at **52** and the top of the inner annular column **33** at **54**. Thus, the seal may be maintained over a wide range of liquid pressure which determines a minimum height of annular columns **36** and **38**, that is definitive of the height of the swivel joint.

Additionally, a secondary seal, preferably mercury, is provided between the major streams and secondary streams, and comprises outer annular column **136** and inner annular column **138** in secondary sheaths **118**. The secondary seal also is adjustable to variances in the pressure difference between the major liquid stream and the secondary liquid stream. The instantaneous pressure difference is equivalent to the height of mercury between the top of inner annular column **138** at **154** and outer annular column **136** at **152**. As shown in FIGURE 3, the pressure of the crude oil is slightly greater than that of the ballast water.

As is the case in the single stream swivel joint, since mercury is used as the seal liquid in the multiple stream swivel joint, of necessity a non-electrolytic immiscible seal is provided between the mercury and seawater as well as between the secondary mercury seal and ballast water to prevent electrolytic corrosion of metal parts of the swivel joint. Suitable materials therefor are described above. Accordingly, a non-electrolytic seal **53** is maintained above outer annular column **36** of the mercury seal in sheath **18**, while a secondary non-electrolytic seal **153** is maintained above inner annular column **138** of the mercury seal in secondary sheath **118**. Above non-electrolytic seal **53** is seawater in surge zone **55**, free to move in and out through slots **56** as the mercury seal moves up and down due to pressure changes of the transported crude oil. Above the seawater in surge zone **55** is an oil bath **137**, of a mineral oil, enclosed by shroud **58**, and lubricating radial and thrust bearing **135**.

As hereinabove mentioned, the use of an underwater single or multiple stream swivel joint, virtually maintenance- and trouble-free, comprising fixed conduit **14**, movable conduit **16** and a mercury seal, makes possible an improved offshore mooring and loading system, whereby a loading platform, on a horizontally rotatable, vertically pivoted boom, is able to move up and down at least in part with the moored tankship and to rotate with the wind or current about the mooring point. These improvements as embodied by preferred and alternative systems are illustrated by FIGURE 5, 6 and 7, wherein the movement of a tankship during loading and its effect on the preferred systems of the present invention are diagrammatically shown, as well as systems utilizing alternative embodiments shown, as well as systems utilizing alternative embodiments of the components of the invention.

FIGURE 5 is a vertical elevation view of a preferred mooring and loading system embodying the single point mooring system of the present invention. Under normal operation, tankship **61** is moored by mooring line **65** secured to float **49** and loaded as shown by the solid lines of FIGURE 5. At high tide, however, or otherwise when tankship **61** is in a higher position, the system adapts itself, as shown exaggerated by dotted lines, to compensate at least in part for the movement of the tankship.

The system as illustrated by FIGURE 5 comprises a mercury seal swivel joint **62** as hereinabove described, anchored in cement foundation **63**, by which fixed submarine line **40** is operatively connected to a rotatable conduit **16** to which is connected at least one flexible line **48**. Flexible line **48**, supported by boom **50**, leads to loading platform **64** where connection can be made with tankship **61**. Alternatively, a floating line may be substituted for boom **50**, flexible line **48** and platform **64**, particularly in areas of mild sea conditions.

Tankship **61** is moored to swivel joint **62** at connection **66** by mooring line **65**. If desired, when not in operation a float **49** secured to the end of float line **57**, may be utilized to provide means both to locate the mooring line and to gain access thereto.

Loading platform **64** is provided with at least one connecting conduit **68** and valve **70** for connection with the tankship amidships manifold. The platform **64** is secured to the tankship **61** by lines **72**, which secure the platform **64** at the side of the ship so that it may move at least in part with the tankship **61** without undue stress upon connecting joints and equipment.

As the ship **61** moves vertically, due to changes in draft or tide during loading, the secured loading platform **64** moves in part therewith and the pivoted boom **50** and loading line **48** pivot to compensate for the movement, as shown exaggerated by dotted lines in FIGURE 5. Typically, the boom arm is about 500–800 feet in length depending upon the mooring scheme employed. Since tide and draft variations seldom would raise or lower the area more than 5–10 feet distortion of the system is minimal. Thus, the distortion of the loading system is readily absorbed by the pivoted boom **50** with little strain on the ship's equipment or connections. Preferably, the loading platform is elevated to a height when secured to tankship **61** by loading lines **72** to allow boom **50** to be substantially horizontal at mean low tide.

FIGURE 6, as a top view of a moored tankship, illustrates an alternate mooring scheme, the single point mooring system with yoke, as does FIGURE 7 in a front view, and the compensation of the loading system for changes in wind direction or current, causing the tankship to rotate about its mooring point.

Tankship **61** is moored by lines **65** connected to buoys **49** secured by lines **57** to each end of mooring yoke **74**. Mooring yoke **74** is secured to swivel joint **62** atop header **30** by universal swivel connection **76** and is free to rotate about a vertical axis with the moored tanker and the swivel joint and boom system.

The solid lines of FIGURE 6 illustrate the mooring of tankship **61** with wind and current from the direction indicated by the solid arrow. The swivel joint **62** of the loading system described hereinabove is located at a point substantially coincident below the bow of tankship **61**. Since the bow of the tanker in the single point mooring system with yoke is directly above swivel joint **62**, as shown in FIGURE 6, boom **50** to accommodate 150,000 d.w.t. tankers need be only about 500–600 feet long. Accordingly, for a single point mooring system (without yoke) boom **50** of necessity is longer, about 800 feet (see FIGURE 5). Loading platform **64**, if so desired, may be able to rotate about the outboard end of boom **50** to remain substantially parallel to tankship **61**. Connecting lines **78** run from amidships manifold **80** to connecting valves **70** located on loading platform **64**. Beneficially, the entire loading system, as shown by FIGURES 5 and 6, with the exception of loading platform **64** and a vertical portion of loading boom **50**, is located entirely underwater below the low level position of the ship's hull. Consequently, the ship is free to ride over the loading system, with the virtual elimination of danger of damage thereto by ramming, as shown by FIGURES 5 and 6.

With reference to FIGURE 6, it is seen that as the wind and current shift to the direction indicated by the dotted arrow, the tankship **61**, loading platform **64** and boom **50** rotate substantially about the mooring point as the ship assumes the position as shown by dotted lines.

The present system allows loading or unloading of a tanker from loading platform **64** from the starboard, as

shown in FIGURES 5 and 6. Loading from port side is also readily accomplished as shown in FIGURE 7, a view from the bow of a tanker moored by a single point mooring system with yoke.

Referring now to FIGURE 7, there is seen a single point mooring system with yoke comprising a submerged swivel joint 62 partially buried at sea bottom 12, rotatable conduit 16 and header 30, universal swivel connection 76, mooring yoke 74, float lines 57 and float 49. Tanker 61 is moored to floats 49 at connections 66 by mooring lines 65. Boom 50, pivoted on header 30 of swivel joint 62 by pivots 51, extends to loading platform 64 at midship and supports loading lines 48 running from header 30 along boom 50 to connecting conduits 68 on loading platform 64. Connection between the amidships manifold of tanker 61 and connecting conduit 68 is made by connecting lines 78 at valves 70. The position of tanker 61 shown in FIGURE 7 is at high tide; consequently loading platform 64 is elevated somewhat by pivoting boom 50 from the horizontal at pivot 51.

As hereinabove disclosed by utilization of the method and systems of the present invention, an improved offshore mooring and loading system is achieved, whereby a loading platform, on a horizontally rotatable, vertically pivoted submerged boom, is able to move up and down at least in part with the tankship due to variations in tides or draft, as shown in FIGURES 5 and 7, and to rotate about a mooring point with the tankship due to variations in wind and current, as shown in FIGURE 6. Consequently, damage from ramming or undue stress on the ship's equipment is virtually eliminated and offshore loading, significantly facilitated. The benefits of these improved methods and systems are essentially made possible by the use of one or more underwater mercury swivel joints, and by the novel combinations and methods described herein.

Additional modifications and improvements utilizing the discoveries of the present invention can be readily anticipated by those skilled in the art and may fairly be presumed to be within the scope and purview of the invention as defined by the claims that follow.

I claim:

1. An offshore mooring and ship loading and unloading system, suitable for the transfer of a liquid between shore facilities and a moored vessel, which comprises as elements in combination (1) a swivel joint located on sea bottom and comprising a fixed conduit, a movable conduit having an open bottom end and rotatable about a vertical axis, a substantial length of which is located within said fixed conduit, a fixed sheath located within said fixed conduit and substantially concentric with said movable conduit, said sheath adapted to receive a substantial length of said movable conduit, said sheath being partially filled with and adapted to retain mercury to provide a continuous seal between said liquid and seawater, said fixed conduit and said movable conduit adapted to be in liquid communication, said fixed and movable conduits being closed in a manner to exclude seawater from the interiors thereof, and means to substantially prevent vertical movement of said movable conduit; (2) a submarine line extending from and operatively connecting said shore facilities to said fixed conduit of said swivel joint; (3) a horizontally rotatable, vertically pivoted submerged boom attached to and extending radially from said movable conduit component of said swivel joint; (4) a vertical support located at the outboard end of said submerged boom and extending upwardly above water; (5) a loading platform supported above water by said vertical support; (6) a flexible loading line extending from and connecting said movable conduit component of said swivel joint to connecting means upon said loading platform, said loading line being adjacent and supported by said submerged boom and said vertical support, said connecting means adapted to effect liquid communication between said moored vessel and said flexible loading line.

2. In an offshore mooring and ship loading and unloading system for transfer of a liquid between shore facilities and a vessel, the combination of:

(a) a swivel joint submerged in seawater on sea bottom at a depth sufficient to preclude contact with a vessel moored adjacent thereto, which swivel joint comprises a fixed conduit, a movable conduit within said fixed conduit and rotatable about a substantially vertical axis, a mercury seal continuous between said fixed conduit and said movable conduit of a height sufficient to balance a pressure differential between said liquid being transferred and said seawater, a non-electrolytic liquid seal between said mercury seal and said seawater, which non-electrolytic liquid is immiscible to, and has a specific gravity intermediate, mercury and said seawater, whereby said non-electrolytic seal precludes electrolytic corrosion of metal parts of said submerged swivel joint;

(b) means to moor said vessel so that the bow thereof is above and in the vicinity of said submerged swivel joint, said mooring means permitting rotation of said vessel about the bow thereof;

(c) a fixed submarine line extending from shore storage facilities to said submerged swivel joint, which submarine line operatively provides conduit means between said shore storage facilities and said fixed conduit of said submerged swivel joint;

(d) a rotating boom pivotally attached at one end to said movable conduit, said boom extending radially from said submerged movable conduit substantially parallel said vessel to a point adjacent amidship thereof, said boom being rotatable with said vessel and said movable conduit about a vertical axis and being rotatable about a horizontal axis at the pivotally attached end, said boom being submerged to a depth sufficient to preclude contact of said vessel therewith;

(e) a vertical support extending upwardly above water from the end of the rotating boom not pivotally attached;

(f) an above-water loading platform, supported by said vertical support, adjacent midships of said vessel;

(g) at least one fluid connecting means upon said loading platform;

(h) at least one loading line extending from said swivel joint to said loading platform, which loading line is supported by and adjacent to said rotating boom and said vertical support, and which operatively provides conduit means between said movable conduit of said submerged swivel joint and said fluid connecting means upon said loading platform, said fluid connecting means adapted to effect fluid communication between said vessel and said loading line.

3. A swivel joint, suitable for use submerged in seawater, which comprises a fixed vertical cylindrical conduit closed at both ends fitted with a side flanged opening; a movable vertical conduit having substantially the same vertical axis and about ¼ to ¾ the diameter of said fixed conduit, one open end thereof located near and inside a bottom closed end of said fixed conduit, another end thereof extending through a top closed end of said fixed conduit and said movable conduit provided with at least one opening at a top end thereof; a vertical cylindrical sheath encasing said movable conduit from its bottom open end to a position above said side flanged opening of said fixed conduit and closing a top end of said fixed conduit in an annulus bounded by said fixed conduit and said movable conduit, which sheath comprises two concentric cylinders, an inner cylinder and an outer cylinder, the bottom annulus therebetween being closed, enclosing therebetween said movable conduit, and a metal ring extending from the top end of said outer cylinder to said fixed conduit which closes the annulus between said outer cylinder and said fixed conduit; a mer-

cury seal within said sheath and having an outer annular column in an annulus bounded by the outside of said movable conduit and the inside of said outer cylinder of said sheath and an inner annular column in an annulus bounded by the outside of said inner cylinder of said sheath and the inside of said movable conduit, said annular columns joined at their bases at the bottom of said sheath; a water-immiscible, non-electrolytic fluid seal having a density intermediate the densities of mercury and seawater, which seal is above said outer cylindrical leg of said mercury seal; and means to prevent vertical motion of said movable conduit while permitting rotating motion thereof.

**4.** An underwater swivel joint suitable for transferring fluid between a shore facility and a moored vessel which comprises a fixed vertical conduit being adapted to effect fluid communication with a loading line leading to said storage facility, a vertical cylindrical conduit rotatable about a vertical axis adapted to effect fluid communication with a loading line leading to said moored vessel, said rotatable conduit having a smaller diameter than said fixed conduit, said rotatable conduit having an open bottom portion and being in fluid communication with said fixed conduit, a fixed annular cylindrical sheath of an outside diameter intermediate said fixed conduit and said rotatable conduit and being substantially concentric with said rotatable conduit, said sheath being adapted to receive said rotatable conduit, said sheath being partially filled with and adapted to retain mercury to effect a seal between outside water and fluid being transferred between said moored vessel and shore facility, said fixed and rotatable conduits being closed in a manner to exclude seawater from the interiors thereof, and means to substantially prevent vertical motion of said rotatable conduit.

**5.** An underwater swivel joint adapted for simultaneously transferring a plurality of fluids between a moored vessel and shore facilities which comprises a lower fixed portion and an upper movable portion rotatable about a vertical axis, said lower fixed portion comprising a plurality of conduits of different diameter, said upper portion comprising a plurality of conduits open at their lower end and equal in number to the conduits in the lower fixed portion, each conduit in said upper portion being in fluid communication with a corresponding conduit in said lower portion; a plurality of fixed sheaths corresponding to the number of conduits in said movable upper portion, said sheaths being adapted to receive the conduits in said upper movable portion, said sheaths being partially filled with and adapted to retain mercury to effect a seal between fluid being transferred in a given conduit and both outside water and fluids in the remaining conduits, said fixed and rotatable conduits being closed in a manner to exclude outside water from the interiors thereof, means for effecting fluid communication between the conduits in said fixed portion and shore facilities, means for effecting fluid communication between the conduits in said movable portion and a moored vessel and means to substantially prevent vertical motion of said movable upper portion.

**6.** A system for simultaneously transferring a plurality of fluids between a shore facility and a moored vessel which comprises (1) a swivel joint located on sea bottom and comprising a fixed lower portion having a plurality of fixed conduits having different diameters, a movable upper portion having a pluraltiy of conduits rotatable about a vertical axis being open at their bottom ends and equal in number to the number of fixed conduits, a plurality of fixed sheaths corresponding to the number of rotatable conduits, said sheaths each adapted to receive a substantial length of a rotatable conduit, said sheaths being partially filled with and adapted to retain mercury to provide a continuous seal between a fluid being transferred and both fluids being transferred in other conduits and seawater, said rotatable conduits each adapted to be in fluid communication with a separate fixed conduit, said fixed and movable conduit being closed in a manner to exclude seawater from the interiors thereof, and means to substantially prevent vertical motion of said movable upper portion; (2) a plurality of submarine lines each extending from and operatively connecting said shore facilities and a fixed conduit of said swivel joint; (3) a horizontally rotatable, vertically pivoted submerged boom attached to and extending radially from the movable portion of said swivel joint; (4) a vertical support located at the outboard end of said submerged boom and extending upward above water; (5) a loading platform supported above water by said vertical support; (6) a plurality of flexible loading lines each extending from and connecting a rotatable conduit of said swivel joint to connecting means upon said loading platform, said loading line being adjacent and supported by said submerged boom and said vertical support, and said connecting means adapted to effect fluid communication between said moored vessel and said flexible loading lines.

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