United States Patent [19]

Lloyd et al.

[11] **3,766,582**

[45] **Oct. 23, 1973**

[54] **OFFSHORE STRUCTURE HAVING A REMOVABLE PIVOT ASSEMBLY**

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[73] Assignee: **Esso Production Research Company**, Houston, Tex.

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[21] Appl. No.: **224,005**

[52] **U.S. Cl.** ..... **9/8 P**, 61/46.5

[51] **Int. Cl.**... **B63b 35/44**, B65d 87/08, E02d 17/00

[58] **Field of Search** ..... 114/9; 9/8 P, 8 R; 61/46, 46.5; 166/0.5

[56] **References Cited**

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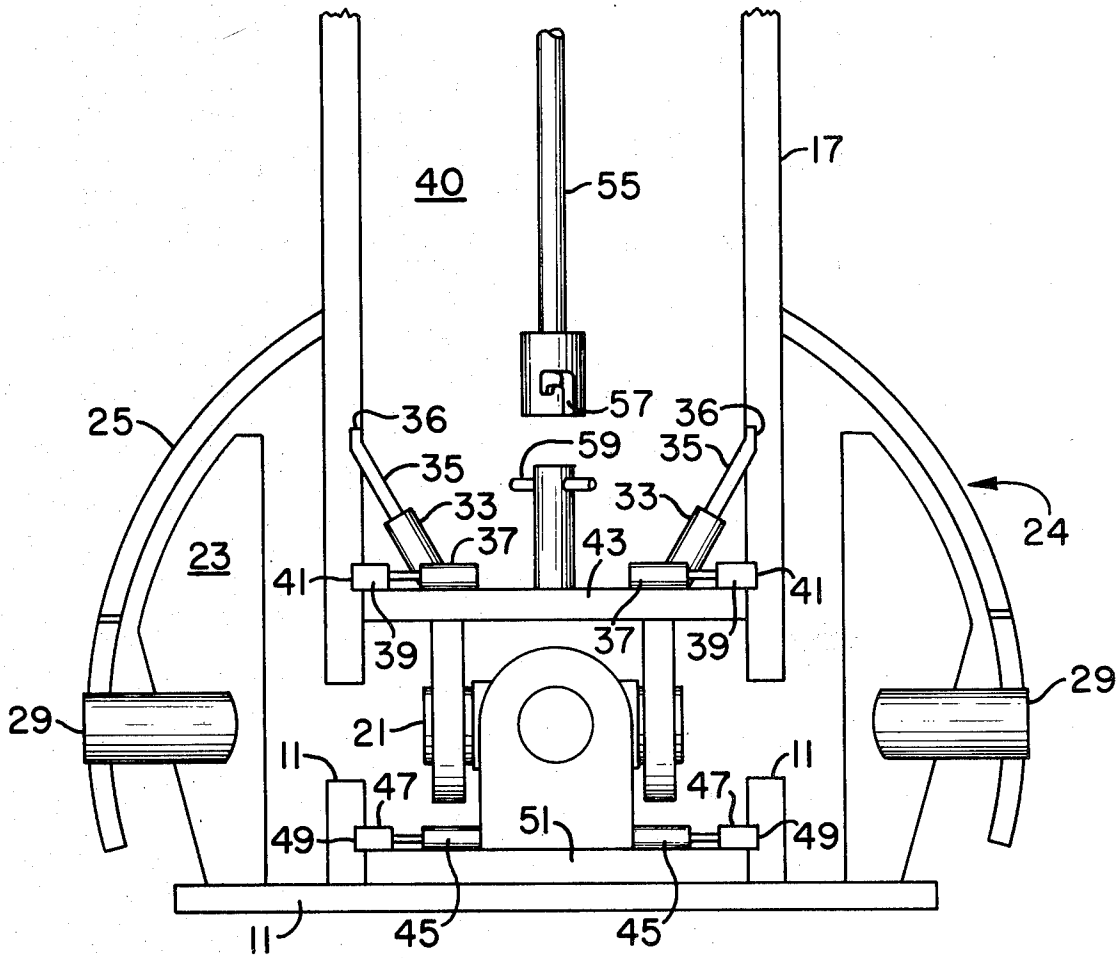
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Primary Examiner—Milton Buchler
Assistant Examiner—Gregory W. O'Connor
Attorney—James A. Reilly et al.

[57] **ABSTRACT**

A buoyant tower having a removable pivot assembly is disclosed. The apparatus includes a base provided with means for anchoring it to the bottom of a body of water, an elongated tower that extends upwardly from the base and a buoyancy chamber attached to the tower near its upper end and positioned to remain at least partially submerged beneath the water surface when the tower is installed in a body of water. A primary pivot assembly interconnects the tower and the base and is provided with means for disengaging the same. An auxiliary pivot assembly is included in the tower structure and is situated adjacent the primary pivot assembly. This auxiliary pivot interconnects the tower and base when the primary pivot is disengaged.

11 Claims, 5 Drawing Figures



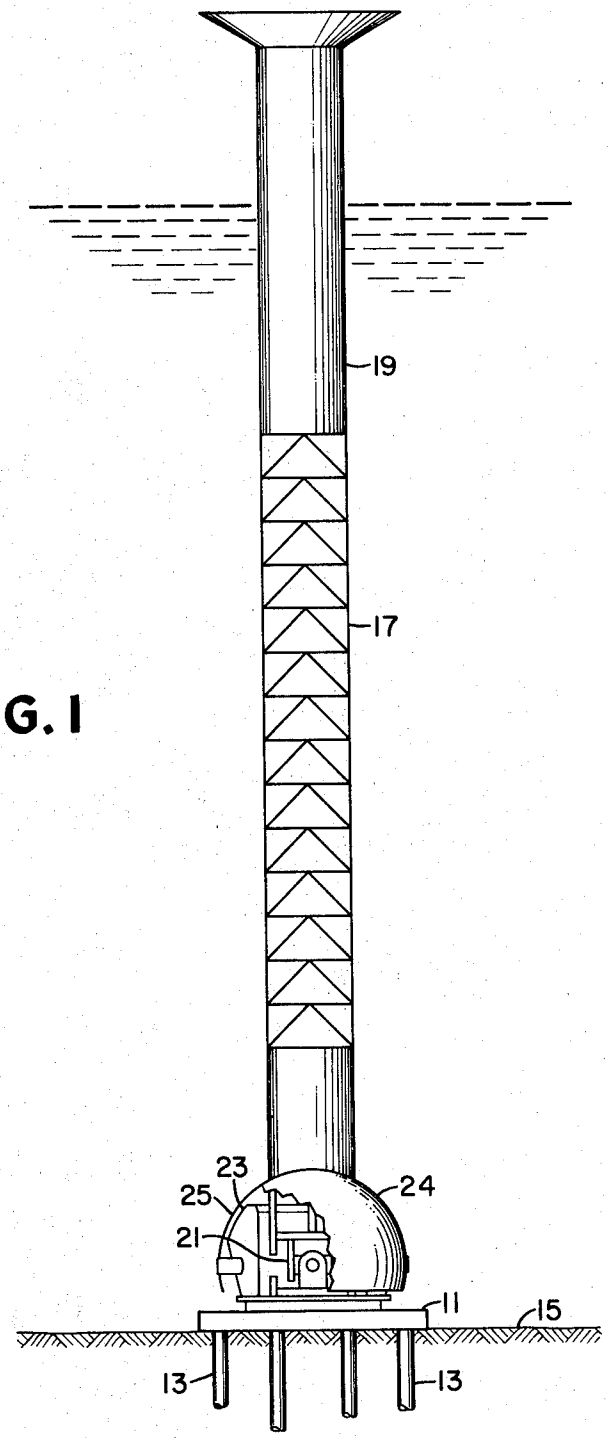


FIG. 1

FIG. 2

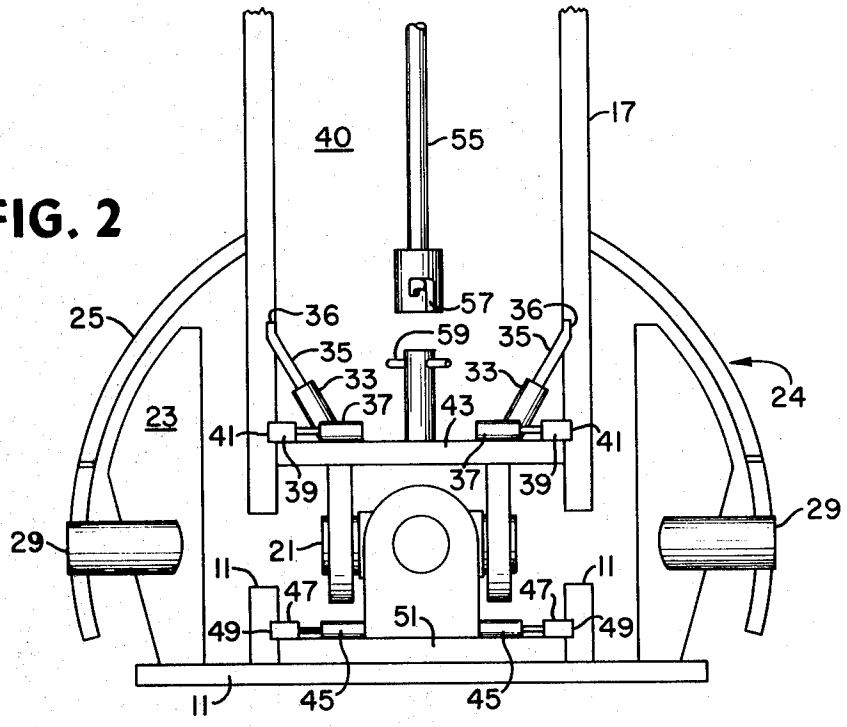
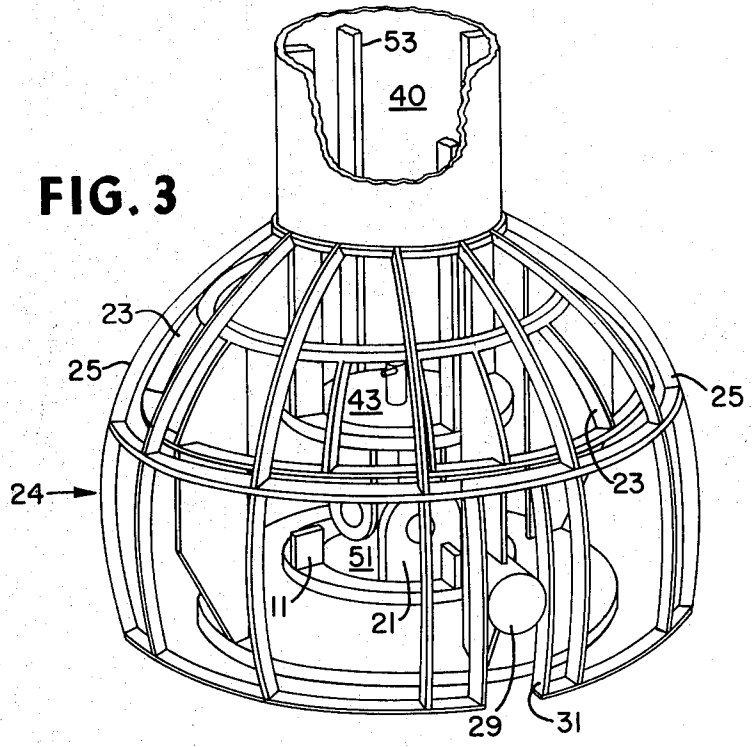

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FIG. 3


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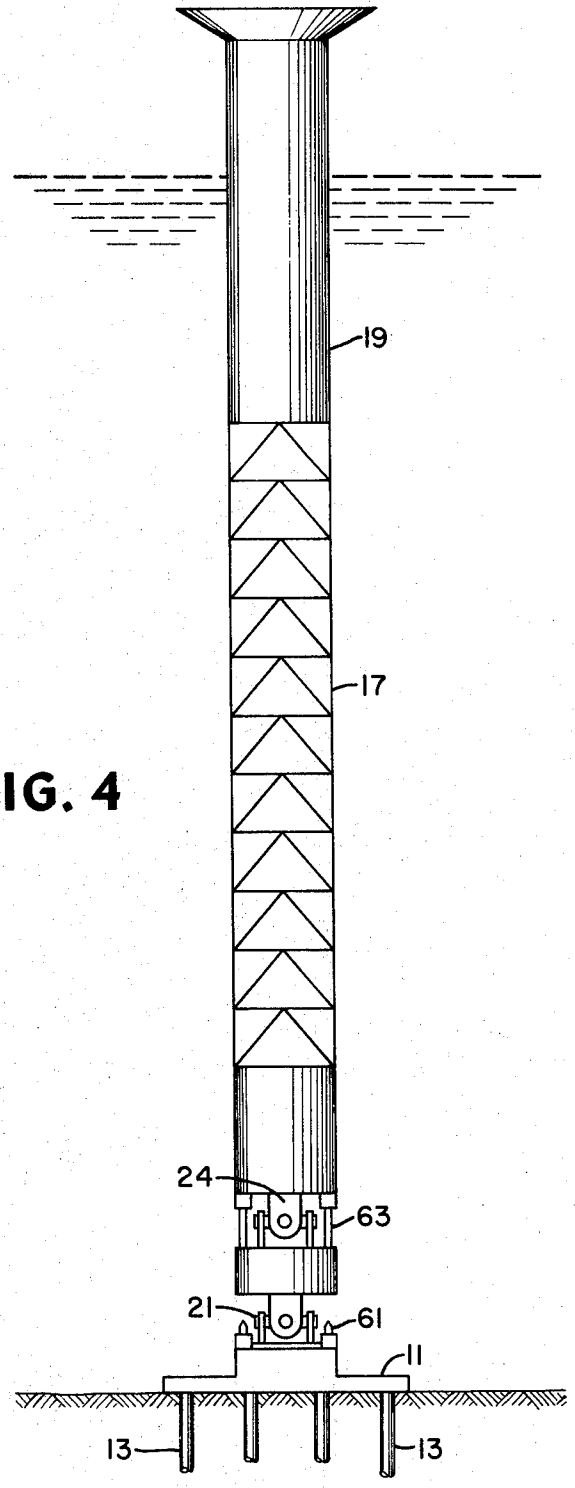


FIG. 4

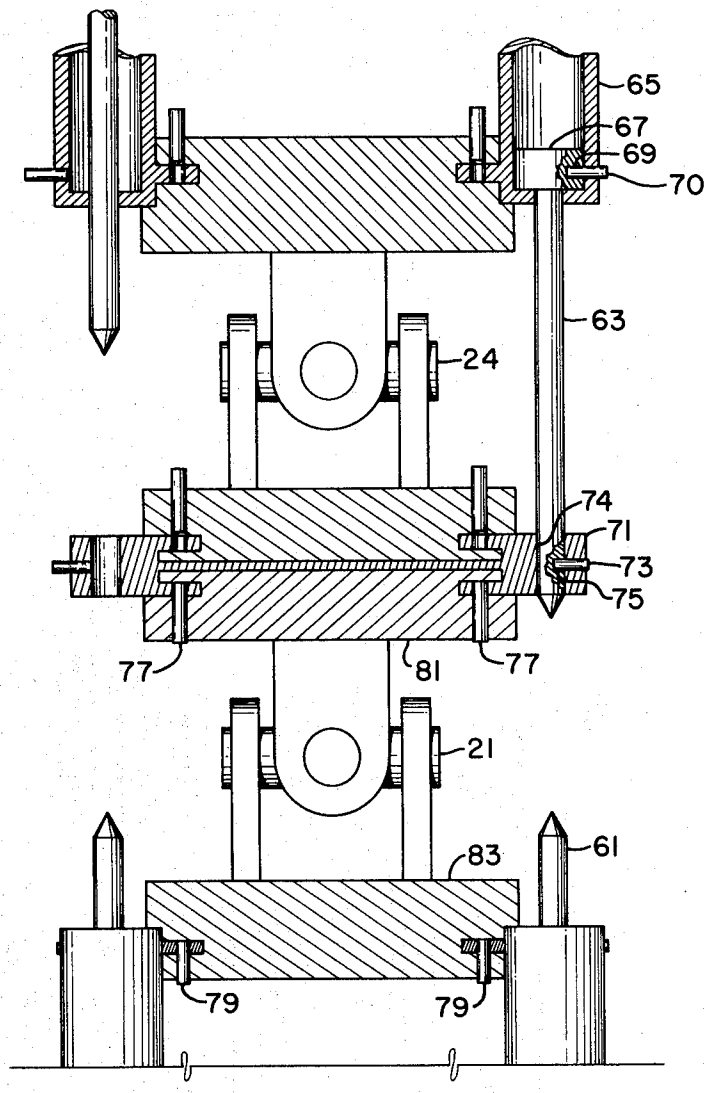


FIG. 5

OFFSHORE STRUCTURE HAVING A REMOVABLE PIVOT ASSEMBLY

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to apparatus which permits removal of the pivot assembly interconnecting a buoyantly supported tower to a base anchored to a submerged bottom without disrupting normal functioning of the tower.

2. Description of the Prior Art

As efforts directed toward exploration for and production of crude oil and natural gas are extended into deeper waters, depths will ultimately be reached which will make impractical the rigid, bottom-founded platforms presently employed to support such operations. One alternative for deep water operations is a buoyantly supported tower which extends from the water surface to the marine bottom. Such structures normally include a base anchored to the submerged bottom, an elongated tower having at least one buoyancy chamber near the upper end, and a pivot assembly that connects the tower to the base, permitting the tower to sway in response to environmental forces.

It is important to the function of a buoyantly supported tower serving to support equipment for the production of crude oil offshore that the pivot assembly, which normally includes a universal joint or ball joint, remain operative for extended periods of time. The pivot assemblies for such multiton structures will be massive and will be subjected to continuous swaying of 2° to 3° from vertical in any direction as a result of the action of wind, waves and ocean currents. During storms, tower sway may occasionally attain a magnitude of 5° to 10°. The difficulties encountered in lubricating the sliding surfaces of the submerged pivot are substantial and, unless overcome, may substantially shorten its operating life. Moreover, the corrosive brine environment also tends to reduce the operating life of the pivot assembly. Because buoyantly supported towers will frequently be installed in water depths in excess of diver capabilities, maintenance of the underwater pivot assembly in place will pose serious difficulties. On the other hand, retrieval of the pivot assembly for maintenance above the water surface has heretofore required the entire buoyantly supported tower to be detached from the base assembly. It will therefore be apparent that a need exists for a system which will facilitate maintenance or replacement of the pivot assembly to assure its continued operation in the corrosive underwater environment.

SUMMARY OF THE INVENTION

The present invention enables the pivot assembly to be removed and retrieved for periodic maintenance without interrupting operation of the tower and will therefore alleviate the problems outlined above. The apparatus of the invention includes a base provided with means for anchoring the same to the bottom of a body of water, an elongated tower that extends upwardly from the base toward the surface of the body of water and at least one buoyancy chamber attached to the tower near its upper end and positioned to remain at least partially beneath the water surface when the tower is installed in a body of water. A primary pivot assembly interconnects the tower and base and is provided with means for disengaging the same. An auxiliary pivot assembly is situated on the tower structure adjacent the primary pivot assembly and pivotally interconnects the tower and base when the primary pivot assembly is disengaged.

The apparatus of the invention permits the load normally carried by the primary pivot to be transferred to the auxiliary pivot. With the buoyantly supported tower pivotally connected to the base by the auxiliary pivot, the primary pivot assembly may be removed for maintenance at the surface or replacement. It will therefore be apparent that the present invention offers significant advantages over systems available heretofore.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic elevation of a buoyantly supported tower which includes one embodiment of a removable pivot assembly constructed in accordance with the invention.

FIG. 2 is an enlarged cutaway elevation view of the apparatus shown in FIG. 1 and depicts in detail the primary and auxiliary pivot assemblies.

FIG. 3 is an enlarged perspective view of an alternative construction of the auxiliary pivot assemblies of FIGS. 1 and 2.

FIG. 4 is a schematic elevation of a buoyantly supported tower which includes another embodiment of a removable pivot assembly constructed in accordance with the invention.

FIG. 5 is an enlarged schematic elevation view, partially in section, of the removable pivot assembly of FIG. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

With respect to FIG. 1 of the drawing, in which identical numerals have been used to designate identical structural elements, a base 11 is shown anchored by a number of pilings 13 to a submerged bottom 15. An elongated tower 17 having a single buoyancy chamber 19 integrally connected to its upper end is connected to the base by a primary pivot, shown as universal joint 21, which permits the tower to sway in response to environmental forces. An auxiliary pivot assembly designated generally by numeral 24 is also shown and is comprised of a spherical bearing surface 23 supported by base 11 and a spherical skirt 25 attached near the lower end of the tower and configured such that when it is lowered into contact with bearing surface 23 it will mate with and slidably engage the same.

FIGS. 2 and 3 are enlarged views of the removeable pivot assembly embodied in the buoyantly supported tower depicted in FIG. 1. Spherical bearing surface 23 and spherical skirt 25 are shown in FIG. 2 as continuous surfaces and in FIG. 3 as constructed of a number of curved structural members which are joined together to form spherical surfaces. The bearing surfaces may be constructed of steel or a corrosion resistant alloy.

Primary pivot assembly 21 is shown as a universal joint. It will be apparent, however, that other joints, as for example ball joints, may also be used with the apparatus of the invention, the primary requirement being that the flexible joint used be capable of pivoting in any direction and be capable of extended unattended service in the corrosive subsea environment. The pivot will normally be a massive structure and for a buoyantly supported tower used in connection with produc-

tion of crude oil and natural gas it can have a weight on the order of 100 tons.

The means for functionally disengaging the primary pivot assembly shown in FIG. 2 of the drawings is a hydraulically actuated system. An electric system or other remotely actuatable arrangment of apparatus for carrying out this function could also readily be employed. Primary hydraulic cylinders 33 extend between the pivot assembly and the lower end of tower 17. Two primary hydraulic cylinders are shown in FIG. 2 and are attached to plate 43 by pivots, not shown, which plate is in turn connected to the primary pivot. Although only two primary cylinders are shown in the drawings, four or more would normally be utilized. Hydraulic fluid is introduced into primary cylinders 33 to extend rods 35 into receptacles 36 in tower 17. Introduction of fluid is continued and pressure is increased until the force generated by the hydraulic cylinders balances the downwardly directed force imposed on the primary pivot assembly by tower 17. In this connection it will be understood that in the embodiment of the invention shown in FIGS. 1–3, prior to disengaging the primary pivot the forces acting throughout the structure should be such that the primary pivot is in compression. It will be noted from FIG. 2 that the position of dogs 39, which normally extend into slots 41 in the lower end of tower 17 and transmit the weight of the tower to plate 43 of the primary pivot assembly, is controlled by upper latching hydraulic cylinders 37. With the weight of the tower supported by the primary cylinders, hydraulic fluid is introduced into the upper latching cylinders so as to retract dogs 39 from slots 41 in the lower end of tower structure 17 and thus free the tower structure to move vertically relative to plate 43. While supported by the primary pistons it will be noted that the tower is free to pivot with respect to the base via the primary pivot. The load of the tower is subsequently transferred from hydraulic cylinders 33 to spherical bearing surface 23 by gradually bleeding off the hydraulic pressure within each of the primary cylinders. These cylinders pivot as they retract, permitting the tower to be lowered onto the auxiliary pivot assembly while supported by the primary cylinders. With the weight of the structure carried by auxiliary pivot assembly 24 formed by spherical surfaces 23 and 25 the primary pivot is functionally disengaged, yet sway of the tower can be tolerated without interrupting or rendering hazardous further operations directed toward physical disconnections and removal of the primary pivot.

The size and surface area of spherical skirt 25 and spherical bearing surface 23 will be governed to a large extent by the load to be transferred from the primary pivot to the auxiliary pivot. This load may be determined from the weight of the tower, including any ballast which may be provided near the lower end, less the sum of the buoyant forces generated by the submerged buoyancy chamber. In addition to the load, consideration should be given to the anticipated angular rotation of the pivot, The skirt must be sized such that tower sway will not force the lower part of the skirt to strike the base assembly. Similarly clearance must be allowed between the skirt and the well conductor pipes which are to be situated adjacent to and around the periphery of the base and which extend upwardly and parallel to the tower structure. In view of the omnidirectional sway of the tower, it will be apparent that a spherical configuration of the bearing surfaces will provide the best joint; however, at some sacrifice to efficiency the surfaces could be constructed somewhat out of round. The construction shown in FIG. 3 wherein the bearing surface 23 and skirt 25 are shown as constructed of a number of curved members joined to form spherical surfaces is particularly advantageous since it results in a substantial reduction in the amount of structural material required to fabricate the auxiliary pivot.

A pair of torque pins 29 are shown mounted on the spherical bearing member 23 and are aligned with this member such that their axes are coincident with and pass through the center of the pivot assembly. These torque pins are shown in the drawing as integrally constructed as a unitary part of the bearing member but could alternatively be forged independently and then journaled or otherwise connected to the bearing surface. Spherical skirt 25 includes a pair of bearing sleeves 31 appropriately aligned and positioned to receive the torque pins on the bearing member when the skirt is lowered onto and concentrically positioned about the spherical bearing surface. The torque pins and their bearing sleeves are an important aspect of the auxiliary pivot assembly depicted in FIGS. 1–3 as they transmit any torque loads resulting from environmental forces acting on the tower to the base and thereby prevent the tower and any conductor pipes associated therewith from rotating with respect to the base.

With the auxiliary pivot assembly interconnecting the tower and base, the primary pivot assembly may be disconnected for removal. Disconnection of the primary pivot is completed by actuation of hydraulic disconnect cylinders 45 which retract dogs 47 from slots 49 in base assembly 11. This frees plate 51, which supports primary pivot assembly 21, to slide with respect to base 11.

Removal of the pivot is facilitated by a way that extends through the center of the tower from the pivot assembly toward the surface. This way is shown as having a circular cross section and is designated by numeral 40 in the drawings. A series of guide rails 53 may suitably be provided within way 40 to guide the pivot and prevent it from swaying from side to side as it ascends and thereby possibly damaging the tower. Lifting of the pivot through the way may, for example, be accomplished by lowering running tool 55 from the surface until an engagement means situated at the lower end of the tool engages and locks the running tool to the pivot assembly. This engagement means may include a J-slot 57 on the lower end of running tool 55 which receives and locks therewithin a corresponding outwardly extending dog 59 mounted on the upper end of the primary pivot assembly. Once the running tool and pivot assembly are locked together, the running tool is withdrawn to the surface via the way thereby raising the pivot assembly to the surface.

The pivot assembly can be refurbished at the surface prior to replacement or alternatively may be replaced by a new pivot assembly. In either event, the running tool is locked to the pivot prior to replacement and the pivot is lowered downwardly through way 40 with the same hoist or lifting apparatus used to withdraw the pivot. As the pivot is lowered it will be guided by the rails 53 within the way until the pivot assembly is positioned such that plate 51 is resting atop base 11 and disconnect dogs 47 are aligned with the corresponding slots 49 in the base assembly. Hydraulic disconnect cylinders 45 are then actuated to extend dogs 47 into slots

49 of the base assembly. With the primary pivot again connected to the base, primary hydraulic cylinders 33 are actuated to extend rods 35 into slots 36 situated near the lower end of the tower structure. With the extensible rods positioned within slots 36, hydraulic pressure within the primary cylinders is increased, further extending rods 35 and lifting the tower and skirt 25 off bearing surface 23. Upraising of the tower is continued until slots 41 near the lower end thereof are in register with dogs 39. With the tower and pivot assembly thus aligned, the upper latching cylinders 37 are actuated hydraulically to extend dogs 39 into slots 41 in the lower end of the tower. The primary hydraulic cylinders 33 may then be bled off so that the weight of the tower is once again transferred through dogs 39 to plate 43 of the primary pivot assembly. This in effect re-engages the primary pivot assembly.

Shown in FIGS. 4 and 5 of the drawings is another embodiment of the apparatus of the invention. As will be noted from FIG. 4, the primary pivot assembly 21 and auxiliary pivot assembly 24 are positioned in series along the length of tower 17. Retractable bridging bars 61 are employed to functionally disengage the primary pivot assembly so that the loading normally carried by the primary pivot may be shifted to the auxiliary pivot assembly.

The features of the primary and auxiliary pivot assemblies together with the apparatus for disengaging each pivot assembly are shown in detail in FIG. 5. It will be noted that primary pivot assembly 21 and auxiliary pivot assembly 24 are positioned atop one another. Retractable bridging bars 61 associated with the primary pivot assembly 63 and associated with the auxiliary pivot assembly, are shown in the position they occupy when extended and retracted. The position of the bridging bars is preferably controlled hydraulically and appropriate hydraulic gear is exemplified by that shown in cutaway in FIG. 5 in which a cylinder 65 is depicted, the upper end of which is attached to the lower end of the rigid tower. Shown within cylinder 65 is a piston 67 which is rigidly connected to one end of bridging bar 63. Introduction of hydraulic fluid into the cylinder on either side of the piston will either extends or retract the bridging bar. Each piston has a receptacle therein as exemplified by the slot designated by numeral 69. Each such slot is adapted to receive a hydraulically extensible locking pin 70 which serves to lock the piston and thereby the bridging bar in the extended position. During normal operations, bridging bars 63 associated with the auxiliary pivot assembly would be fully extended and locked into frame member 71 by hydraulically extensible locking pins 73 which are received within slots 75 in the lower ends of bridging bars 63. With the bridging bars 63 thus extended and locked to frame member 21 and with bridging bars 61, which are associated with the primary pivot assembly, retracted, the primary pivot interconnects the tower and the base and is the only pivot which carries any load.

When it is desired to remove the primary pivot assembly the forces acting on the tower structure must be such that the primary pivot assembly is in tension. The bridging bars 63 associated with the auxiliary pivot may then be freed by releasing hydraulically extensible locking pins 70 and 73 and retracted by introducing hydraulic fluid into the appropriate hydraulic cylinders. The bridging bars 61 associated with the primary pivot assembly are extended hydraulically until the upper ends of bridging bars 61 are positioned within apertures 74 in frame member 71. With the bridging bars thus positioned locking pins are extended to anchor each bridging bar at its extremities. The bridging bars thus rigidly connect the base assembly to frame member 71 whereby the primary pivot assembly is functionally disengaged and the load imposed by the buoyantly supported tower acts only through auxiliary pivot assembly 24.

After the primary pivot assembly is functionally disengaged, upper latching pins 77 and lower latching pins 79 which connect the pivot assembly to the frame member 71 and base assembly 11, respectively, are hydraulically disengaged whereby the primary pivot assembly including upper and lower slotted plate members 81 and 83 respectively, is slidable with respect to the base assembly and frame member 71. A submersible manipulator or similar device may then be employed to slide the primary pivot assembly out of the structure so that it may be lifted to the surface and either refurbished or structure so that it may be lifted to the surface and either refurbished or replaced. Alternatively one or more anchor piles having sheaves thereon may be employed in connection with a hoist on a work boat and a length of cable to withdraw the primary pivot from the structure.

To replace the pivot assembly the refurbished or replacement pivot is lowered into position adjacent the base of the tower assembly and by means of a submersible manipulator or a pulley in combination with pilings is slid back into place. The upper and lower latching pins 77 and 79 may then be extended to rigidly affix the pivot assembly to base 11 and frame member 71. Once this is accomplished and with the auxiliary pivot in tension, the bridging bars associated with the auxiliary pivot assembly are extended and those associated with the primary pivot assembly are unlocked and retracted whereby the load imposed by the tower on the pivot again acts on the primary pivot assembly.

What is claimed is:

1. Offshore apparatus comprising:
   a. a base provided with means for anchoring the same at the bottom of a body of water;
   b. a tower that extends upwardly from said base toward the surface of said body of water;
   c. a buoyancy chamber attached to said tower near the upper end and positioned to remain at least partially beneath the water surface when the tower is installed in said body of water;
   d. a primary pivot assembly pivotally connecting the lower end of said tower to said base and serving to transmit a load imposed by said tower to said base, said pivot assembly adapted to be disengaged therefrom;
   e. an auxiliary pivot assembly connected to the apparatus adjacent the primary pivot assembly and adapted to interconnect said tower and said base when said primary pivot assembly is disengaged; and
   f. means situated on said structure adjacent said pivot assemblies for transferring the load acting through said primary pivot assembly to said auxiliary pivot assembly.

2. The apparatus of claim 1 wherein said auxiliary pivot includes a spherical skirt and a spherical bearing surface configured to mate therewithin.

3. The apparatus of claim 2 wherein said tower includes a vertical way extending therewithin dimensioned to permit said primary pivot assembly to pass therethrough and provided with means for guiding the said pivot assembly as it moves vertically therewithin.

4. The apparatus of claim 2 wherein said spherical skirt is attached to the lower end of said tower and said spherical bearing surface is attached to said base.

5. The apparatus of claim 1 wherein said means for transferring said load to the auxiliary pivot assembly includes a plurality of hydraulic cylinders.

6. The apparatus of claim 2 wherein said auxiliary pivot assembly includes a torque pin interconnecting said spherical bearing surface and said spherical skirt.

7. The apparatust of claim 1 wherein said auxiliary pivot is comprised of a universal joint situated in the tower structure in series with said primary pivot.

8. The apparatus of claim 1 wherein said auxiliary pivot is comprised of a ball joint situated in the tower structure in series with said primary pivot.

9. The apparatus of claim 5 wherein a second plurality of hydraulic cylinders are connected to said apparatus and are situated adjacent said auxiliary pivot assembly.

10. A method of removing a pivot assembly from an offshore structure wherein said structure is of the type including a base anchored to the floor of a body of water, an elongated tower extending upwardly from the base and having a buoyancy chamber situated near its upper end, and including a primary pivot assembly connecting the tower to the base and serving to transmit a load imposed by said tower to said base and an auxiliary pivot assembly for interconnecting said tower and said base when said primary pivot assembly is disengaged, comprising transferring the load acting through said primary pivot assembly to said auxiliary pivot assembly, disengaging said primary pivot assembly from said structure without disaseembling same and withdrawing said primary pivot assembly from the structure.

11. The method as defined by claim 10 wherein said primary pivot assembly is withdrawn from the structure through a vertical way extending vertically through the tower and provided with means for guiding said pivot assembly therethrough.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,766,582 Dated October 23, 1973

Inventor(s) James R. Lloyd and Mark A. Childers

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

Column 5, line 34, change "position" to --positions--.
Column 5, line 43, change "extends" to --extend--.
Column 6, line 21, delete "structure so that it may be lifted to".
Column 6, line 22, delete "the surface and either refurbish or".

Signed and sealed this 24th day of September 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

FORM PO-1050 (10-69)

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