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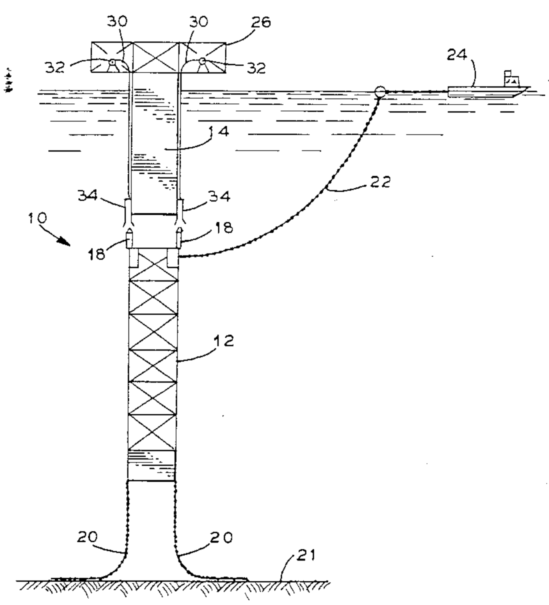
(54) Methods of assembling floating offshore structures

(57) An assembly method involves mating the topsides (26) on a floating offshore structure such as a spar hull (10), joining components of the spar hull (10), and/or a combination or variation of these procedures. Generally, the installation is carried out as follows. Once at the mating site, the spar hull component (12) is upended, outfitted with controls and hardware (20) necessary to effectuate controlled submergence of the spar hull component, and submerged to a predetermined depth below the water surface to have a zero water plane area. The second component (26) to be mated with the top of the spar hull component (12) is positioned to float above the submerged spar hull component (12). The draft of the submerged spar hull component (12) is decreased until the two components (12, 26) are fully engaged.

FIG. 4



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Description

[0001] This invention relates to methods of assembling floating offshore structures, such as in the installation of decks on offshore structures.

[0002] In the offshore drilling industry, unlike ships which can be fully assembled at an inshore facility, many types of oil drilling or production facilities require part of the assembly to take place either at the field location itself or afloat prior to tow to the installation site. For example, it is, by the nature of the design of jacket type production platforms, that the production deck (topsides) be installed after the jacket has been installed and piled to the sea floor. The topsides are typically installed in one or more pieces using heavy lift marine cranes. This can be a costly and weather sensitive operation. Also, additional cost is incurred due to the additional logistical support for the final hook-up of the topsides to the platform which must then take place offshore. The offshore hook-up problem is further aggravated if the topsides requires several lifts and/or the production platform is in a remote location.

[0003] Concrete GBS production platforms and floating production platforms such as Spar Platforms can provide the option, due to their buoyancy capacity, of avoiding the cost associated with offshore heavy lift operations by allowing a "float over" deck installation operation. Using this prior art method, a fully completed deck is loaded on barges in a catamaran configuration, the platform is ballasted down to a reduced freeboard, and the topsides floated over the platform. The platform is deballasted, thereby picking up the topsides and lifting it to the proper elevation above the water line. However, the transport of the topsides and the mating operation itself must take place in fairly benign conditions.

[0004] Due to the large draft of Spar type platforms, the traditional construction sequence, for steel hull Spars, involves the joining of structural sections in the horizontal position, followed by upending of the entire Spar hull to the vertical position. The structural sections may consist of either plated hull tank sections only, or combination of plated tank and truss type sections. Such Spar type platforms are described in U.S. Patents No. 4,702,321 and 5,558,467. As a consequence of a horizontal assembly and upending sequence, the topsides can only be installed after the upending operation and thus must take place in a location with substantial water depth. This can result, depending on geographical location, in either:

the topsides having to be installed offshore in a non-sheltered area, which means the deck transport and installation become weather sensitive operations; or possibly require a long tow of the fully assembled Spar to the production site, if the risk of an offshore deck installation is too high and the topsides must be installed in a sheltered location.

[0005] It can be seen that the present state of the art in the installation of topsides on a floating offshore structure such as a Spar type hull includes shortcomings which have not been adequately addressed.

[0006] Respective aspects of the invention are set out in claims 1, 6 and 25.

[0007] A method embodying the invention provides mating the topsides on a floating offshore structure such as a spar hull, joining components of the spar hull, and/or a combination or variation of these procedures. Generally, the installation is carried out as follows. The spar hull component is towed to the mating site and upended, outfitted with controls and hardware necessary to effect controlled submergence of the spar hull component, and is submerged to a predetermined depth, thereby positioning the submerged spar hull component either floating above the seabed or, alternatively, resting on it. The second component to be mated with the top of the spar hull component is positioned above the submerged spar hull component. The draft of the submerged spar hull component is decreased until the two components are fully engaged.

[0008] The invention will now be described by way of example with reference to the accompanying drawings, throughout which like parts are referred to by like references, and in which:

Fig. 1 illustrates a spar hull which has been upended and submerged in position floating above the seabed, with the topsides ready to be moved into position over the hull;

Fig. 2 illustrates the topsides in position over the hull as the hull is moved upward into engagement with the topsides;

Fig. 3 is a plan view of the topsides;

Fig. 4 illustrates a variation of the procedure of Fig. 1 and 2 where the topside and hard tank components have been previously engaged and are then moved into position over the truss component of the spar;

Fig. 5 illustrates a variation of the procedure of Fig. 4 where the hard tank component, without the topsides, is engaged with the truss component;

Fig. 6 illustrates a variation of the procedure of Fig. 1 where a spar hull which has been upended is submerged in position resting on the seabed, with a selected water depth, and bottom portion of the hull penetrating the seabed to a predetermined depth;

Fig. 7 illustrates the topsides in position over the hull of Fig. 6 as the hull is moved upward, thereby reducing the penetration of the bottom hull portion in the seabed and engaging with the topsides;

Fig. 8 illustrates an alternative embodiment of the invention in which shock absorbing materials are provided;

Fig. 9 illustrates an alternative embodiment of the invention in which matching grooves and protrusions are provided on the components;

Fig. 10 is a plan view of the topsides illustrating the protrusions on the structural framing;

Fig. 11 is a plan view of the spar hull that illustrates the grooves on the structural framing;

Fig. 12 is a view taking along lines 12-12 in Fig. 11;

Fig. 13 is a plan view of an alternative embodiment to Figs. 10-12;

Fig. 14 is a view taken along lines 14-14 in Fig. 13;

Fig. 15 illustrates an alternative embodiment of the invention;

Fig. 16 illustrates another alternative embodiment of the invention; and

Fig. 17 illustrates a further alternative embodiment of the invention.

[0009] Fig. 1 illustrates the situation where a floating offshore structure such as a spar hull 10 has been towed to a mating site having sufficient water depth to carry out the mating operation between the topsides 26 and hull 10. The mating site may also be the final operational site. If towed horizontally, the spar hull 10 is upended into its normal vertical operating position and then submerged a predetermined depth below the water surface to provide a zero water plane area (no surface piercing elements) across the spar hull 10. The spar hull 10 illustrated is generally comprised of a truss section 12, a hard tank section 14, and a soft tank section 16. Such a spar hull is described in U.S. Patent No. 5,558,467. For the purpose of the invention, the hard tank section 14 is provided with a plurality of stabbing posts 18 or other arrangement for effecting the alignment and engagement of the components. It should be understood that the type of spar hull shown, a truss spar, is only an example of the type of floating structure that may be used in the method of the invention. Other floating offshore structures, such as a spar hull described in U.S. Patent No. 4,702,321 may also be used in the method of the invention.

[0010] Once the spar hull 10 is upended, weighted draft control lines 20 such as heavy chains, which are partly resting on the sea floor 21, are attached to the lower end of the spar hull 10, and a ballast control line 22, or "life line", is attached between the spar hull 10 and a surface vessel 24 with air compressors on board. The weighted draft control lines may be free hanging from the spar or attached to anchors 11, thereby also serving for station keeping purposes. To increase the weight of the draft control lines, clump weights 13 or bundles of chain can be attached to the lines near the seabed. The spar hull 10 is then submerged by ballasting tanks in the spar hull and, with the aid of the draft control lines 20 which change the submerged weight of the spar hull as chain is lifted on or off the bottom, equilibrium at the desired depth is achieved. The ballast control line 22 is used to control and adjust buoyancy of the spar hull 10 as necessary during ballasting for submergence and, later, deballasting upward into engagement with the topsides 26.

[0011] Alternatively, the submerged depth of the spar hull can be controlled by the ballast control lines 22 in conjunction with a length of buoyancy elements 23 either rigidly or flexibly attached to the top of the hull and floating at the surface. The submerged weight of the structure is changed by the number or length of buoyancy elements pulled below the surface as the hull submergence draft is progressively increased to the desired depth.

[0012] Another useful alternative shown in Fig. 6 is to provide the bottom extremity of the spar hull component 10 with spud piles 15, cans, or a mud mat. This allows the spar hull component to be submerged at a site with pre-determined water depth and soil conditions and ballasted to allow the structure to rest on the sea bed and the spud piles 15, if so provided, to penetrate the sea floor 21. In this manner, spud piles 15 provide station keeping capability by means of shear resistance of the piles in the soil for surviving design level storms while providing sufficient lateral compliancy to avoid large environmentally induced bending loads in the submerged structure. Overturning is prevented by the location of the center of buoyancy being above the center of gravity for the submerged structure.

[0013] Once the spar hull 10 is submerged to the proper depth, either floating above the sea floor or sitting on the sea bed with the spud piles penetrating the sea floor, one or more maneuvering vessels 28 are used to move the self-floating topsides 26 into floating position above the spar hull 10. It should be noted that, depending upon the distance from the fabrication site to the mating site, the topsides may be towed out in a self-floating mode or on a heavy lift vessel and then put afloat during the appropriate weather window. As seen in Fig. 2 and 3, a plurality of mating lines 30 may be used, each engaged with a winch 32 mounted on the topsides 26. The topsides 26 is provided with a plurality of sleeves 34, vertical bores, sized to receive the stabbing posts 18. The mating lines 30 are each run down through their respective sleeves 34 and attached to the stabbing posts 18 using divers or underwater robots. The draft of the spar hull 10 is decreased by deballasting, or winching, or a combination of both to engage the stabbing posts 18 into the sleeves 34. It is desirable for the tension on the mating lines 30 to be at a level sufficient to insure that the stabbing posts 18 remain properly aligned with their respective sleeves 34 and to cause the two components to move together vertically, thereby eliminating contact forces during the mating operation.

[0014] Once the connections between the topsides 26 and spar hull 10 are temporarily secured, the spar hull 10 is deballasted to raise the topsides 26 to a safe freeboard. The connections between the topsides 26 and spar hull 10 are then completed, the ballast control line 22, and draft control lines 20 are removed. If required, solid ballast is then installed. If not already at the final drilling or production site, the completed spar is towed to the final site.

[0015] Alternatively, in Fig. 7, both the topsides and the top of the spar hull component are provided with a plurality of sleeves 34 sized to receive alignment posts 18. The alignment posts 18 are lowered from the topsides 26 through the matching sets of hull and topsides sleeves 34, thereby effectuating alignment of the two components without restraining them vertically. The spar hull is then deballasted to make contact between the hull and topsides and further deballasted to raise the topsides to a safe elevation above the water.

[0016] Fig. 4 illustrates an alternative wherein the truss section 12 and the hard tank section 14 are moved to the mating site as separate components. This allows the topsides 26 to be mated to the hard tank section 14 prior to tow out to the mating site. The stabbing posts 18 or similar arrangement are provided at the upper end of the truss section 12 and the sleeves 34 for receiving the stabbing posts are provided at the lower end of the hard tank section 14. As illustrated, the first component of the offshore structure, the truss section 12 is submerged as described above. The second component of the offshore structure, the hard tank section 14 and topsides 26, are then floated into position above the truss section 12. The draft of the truss section 12 is decreased until the two components are fully engaged. The mating lines 30 and winches 32 are used as described above.

[0017] Fig. 5 illustrates another alternative wherein the components of the offshore structure may be separated into three components (truss section, hard tank section, and topsides), with only the truss section 12 and hard tank section 14 being shown. The mating procedure is carried out as described above. The main difference is that the upper portion of the hard tank section is also provided with stabbing posts 19 which are received in sleeves 34 in the topsides as seen in Fig. 2. The truss section 12 (first component) is submerged, the hard tank section 14 (second component) is floated into position over the truss section 12, and the draft of the truss section 12 is decreased until both of these components are fully engaged. The same procedure may then be used for mating the topsides 26 (third component) to the hard tank section as described above.

[0018] With the forces generated during initial contact of the two components usually being the limiting factors for these types of mating operations, the principles of this invention can be further enhanced to carry out the operations in more severe environmental conditions by incorporating certain provisions, either singly or in combination, into the designs of the spar hull components to be joined together. One means to reduce loads produced during the initial contact stages of the mating operation is to provide the stabbing posts 18 or sleeves 34 with shock absorbing material, indicated by numeral 25 in Fig. 8.

[0019] Another alternative, seen in Fig. 9, is to use the stabbing posts 18 for alignment purposes while allowing the stabbing posts 18 to remain unrestricted vertically within the receptacles 34 throughout the operation. In this case, the floating and submerged components are provided with matching grooves 27 and protrusions 29 to carry out the load transfer and final alignment. The matching grooves and protrusions are provided with shock absorbing material 25, thereby reducing the loads created as the two components are gradually brought into contact. As the matching grooves and protrusions are engaged, the lateral alignment of the two components is secured and full load transfer can take place by deballasting the submerged hull component to the required freeboard.

[0020] It is also considered to be structurally beneficial to have the matching grooves and protrusions 27, 29 aligned with or as extensions of the main structural framing of the hull components to be joined. In the example illustrated in Fig. 10-12, the main structural framing on which the grooves and protrusions 27, 29 are fixed comprises the main structural bulkheads 31A, B respectively in the floating topside component 26 and the submerged spar hull 10.

[0021] Fig. 13, 14 illustrate an alternate embodiment to that of Fig. 10-12 where the matching grooves 29 and protrusions 27 are respectively fixed to a circular ring bulkhead 33 on the topsides 26 and the perimeter of the submerged spar hull 10.

[0022] Fig. 15 illustrates an alternate embodiment to that of Fig. 13-14 where the upper end of the spar hull 10 is provided with a circular shoulder bulkhead 37 around the perimeter of the hull which engages with the circular ring bulkhead 33 in the topsides 26. Fendering 39 may also be provided on the circular ring bulkhead 33. This embodiment eliminates the need for the stabbing posts described above.

[0023] Fig. 16 illustrates another embodiment to those of Fig. 15 and 2 where the circular shoulder 37 around the perimeter of the hull is replaced with an alignment bevel 42 around the bottom perimeter of the circular ring bulkhead 33 on the floating topside 26 to guide the submerged hull 10 as it engages the topsides opening. Also, hydraulic chain jacks 38 or similar hoisting devices are shown to be fixed to heavy plates 43. Heavy plates 43 fit inside deck recesses 45 and are seated on shock absorbing material 25. In combination, the heavy plates 43, shock absorbing material 25, and the deck recesses 45 act as a compliant or shock absorbing plunger assembly 44. The joining with the spar hull 10 is carried out in a similar manner as previously described where the topsides 26 is positioned above the spar hull 10, mating lines 30 are attached to the top of the spar hull 10, and chain stoppers 40 are engaged, thereby locking the mating lines 30 to heavy plates 43. The tension in mating lines 30 is increased by reducing the air pressure in ballast tanks 35 in a controlled manner by means of ballast control line 22, thereby allowing more water to enter the tank through ballast tank inlet 36. Alternatively, water can be pumped into ballast tank 35 by pumping water through ballast control line 22. As the tension is increased to a pre-determined level due to the increasing submerged weight of hull 10, the two components are increasingly caused to move vertically together. During the period between attaching mating lines 30 and to the point that the weight of the submerged spar hull 10 is sufficient to cause the two hull components to move together, any shock loads which could occur in a seaway are absorbed by the shock absorbing plunger assembly 44 on which the chain stoppers are mounted. After attaining the pre-determined tension in the mating lines 30, the chain stoppers 40 are released and the joining operation can continue by operating the chain jacks. Proper lateral alignment of the spar hull 10 and topsides 26 during the engagement operation is aided by alignment bevel 42. This invention allows the two components to be safely joined in seaways without the undesirable impact loads which could otherwise occur using prior art methods. Another benefit of this invention over the prior art is the ability to put operations on hold while waiting on favorable weather or fully reverse the operation at any point of engagement with minimal risk to the two components or personnel. Due to the reversibility of the operation, the invention can also be used to disassemble two spar components which have been joined using the invention.

[0024] Alternatively, in Fig. 17, both the topsides 26 and the top of the spar hull 10 are provided with a plurality of sleeves 34 sized to receive jacking posts 46. The jacking posts 46 are lowered from the topsides 26 through the matching sets of hull and topsides sleeves 34 and are connected to the hull 10 by means of locking connectors 48, thereby effectuating alignment of the two components initially without restraining them vertically. Jack-up devices 47 mounted on the topsides 26 are then activated against jacking posts 46, thereby decreasing the submerged draft of the spar hull component 10 until contact is made in a controlled manner while restraining the undesirable vertical relative motions between the two components caused by environmental forces. In this embodiment of the invention, the step of ballasting or deballasting the submerged component can be eliminated. Also, the use of shock absorbing material can be eliminated by the use of this embodiment. The principles and advantages of this embodiment can be realized using a number of other types of jacking, winching, or hoisting devices generally known in the art.

[0025] Because many varying and differing embodiments may be made within the scope of the inventive concept herein taught and because many modifications may be made in the embodiment herein detailed in accordance with the descriptive requirement of the law, it is to be understood that the details herein are to be interpreted as illustrative and not in a limiting sense.

Claims

1. A method of mating a topsides to the hull of a floating offshore structure, comprising:

   a. submerging the hull of the floating offshore structure to a predetermined depth below the water surface to provide a zero water plane area across the hull of the floating offshore structure;
   b. floating the topsides above the hull of the floating offshore structure; and
   c. decreasing the draft of the hull of the floating offshore structure to cause the topsides and hull to fully engage.

2. The method of claim 1, further comprising attaching draft control lines to the hull of the floating offshore structure before submerging the hull.

3. The method of claim 2, wherein the draft control lines are weighted with one end resting on the sea floor.

4. The method of claim 1, further comprising controlling the buoyancy of the hull through a control line having one end in communication with the hull and the opposite end in communication with buoyancy controls on a surface vessel.

5. The method of claim 3, wherein the control line includes buoyancy elements.

6. A method of mating first and second components of a floating offshore structure, comprising:

   a. submerging the first component of the floating offshore structure to a predetermined depth below the water surface to provide a zero water plane area across the first component;
   b. floating the second component of the floating offshore structure above the first component; and
   c. decreasing the draft of the first component of the floating offshore structure to cause the first and second components to fully engage.

7. The method of claim 6, further comprising attaching weighted draft control lines to the first component of the floating offshore structure before it is submerged.

8. The method of claim 6, further comprising controlling the buoyancy of the first component by attaching buoyant control lines between the first component and a surface vessel.

9. The method of claim 6, further comprising the use of winches and lines to effect engagement of the first and second components.

10. The method of claim 6, wherein the first and second components are respectively provided with stabbing posts and stabbing receptacles.

11. The method of claim 6, further comprising:

a. submerging the first component until said first component rests vertically on the seafloor; and
b. ballasting said first component on the seafloor to achieve a pre-determined on bottom weight.

12. The method of claim 11, further comprising:

a. providing spud piles on the lower portion of the first component; and
b. ballasting the first component until the spud piles penetrate the seafloor to a pre-determined depth.

13. The method of claim 6, wherein the first and second components are respectively provided with matching grooves and protrusions.

14. The method of claim 13, wherein the matching grooves and protrusions are provided with shock absorbing material.

15. The method of claim 13, wherein the matching grooves and protrusions are fixed to the main structural bulkheads of the first and second components.

16. The method of claim 15, wherein the main structural bulkhead of the second component is circular and is aligned with the outer perimeter of the first component.

17. The method of claim 16, wherein the first component is provided with a circular recessed shoulder sized to receive the inner perimeter of the circular bulkhead of the second component.

18. The method of claim 9, wherein the weight of the first component is increased to a predetermined level prior to effecting the engagement of the first and second components.

19. The method of claim 9, wherein the winches are mounted on shock absorbing material.

20. The method of claim 9, wherein said shock absorbing material is contained within a plunger assembly.

21. The method of claim 6, wherein the second component is provided with an alignment bevel.

22. The method of claim 21, wherein one or more main structural bulkheads of the second component are aligned with corresponding main structural bulkheads of the first component.

23. The method of claim 22, wherein said corresponding main structural bulkheads in the first and second components are circular.

24. The method of claim 22, wherein shock absorbing material is fixed to said corresponding main structural bulkheads.

25. A method of mating first and second components of a floating offshore structure, comprising:

a. submerging the first component of the floating offshore structure to a predetermined depth below the water surface;
b. floating the second component of the floating offshore structure above the first component;
c. attaching mating lines between the first and second components ;
d. ballasting the first component to a predetermined weight so as to minimize the relative motions between the first and second components;
e. fully engaging the first and second components by means of winches acting on the mating lines; and
f. raising the second component to a safe elevation above the water surface by deballasting the first component.

26. The method of claim 25, wherein the mating lines are rigid tubular members.

27. The method of claim 25, wherein submergence of the first component provides a zero water plane across the first component.

28. The method of claim 25, wherein the winches are mounted on shock absorbing material.

29. The method of claim 25, wherein the shock absorbing material is contained within a plunger assembly.

30. The method of claim 25, wherein the second component is provided with an alignment bevel.

31. The method of claim 30, wherein one or more main structural bulkheads of the second component are aligned with corresponding main structural bulkheads of the first component.

32. The method of claim 31, wherein the corresponding main structural bulkheads in the first and second components are circular.

33. The method of claim 32, wherein shock absorbing material is fixed to the corresponding main structural bulkheads.

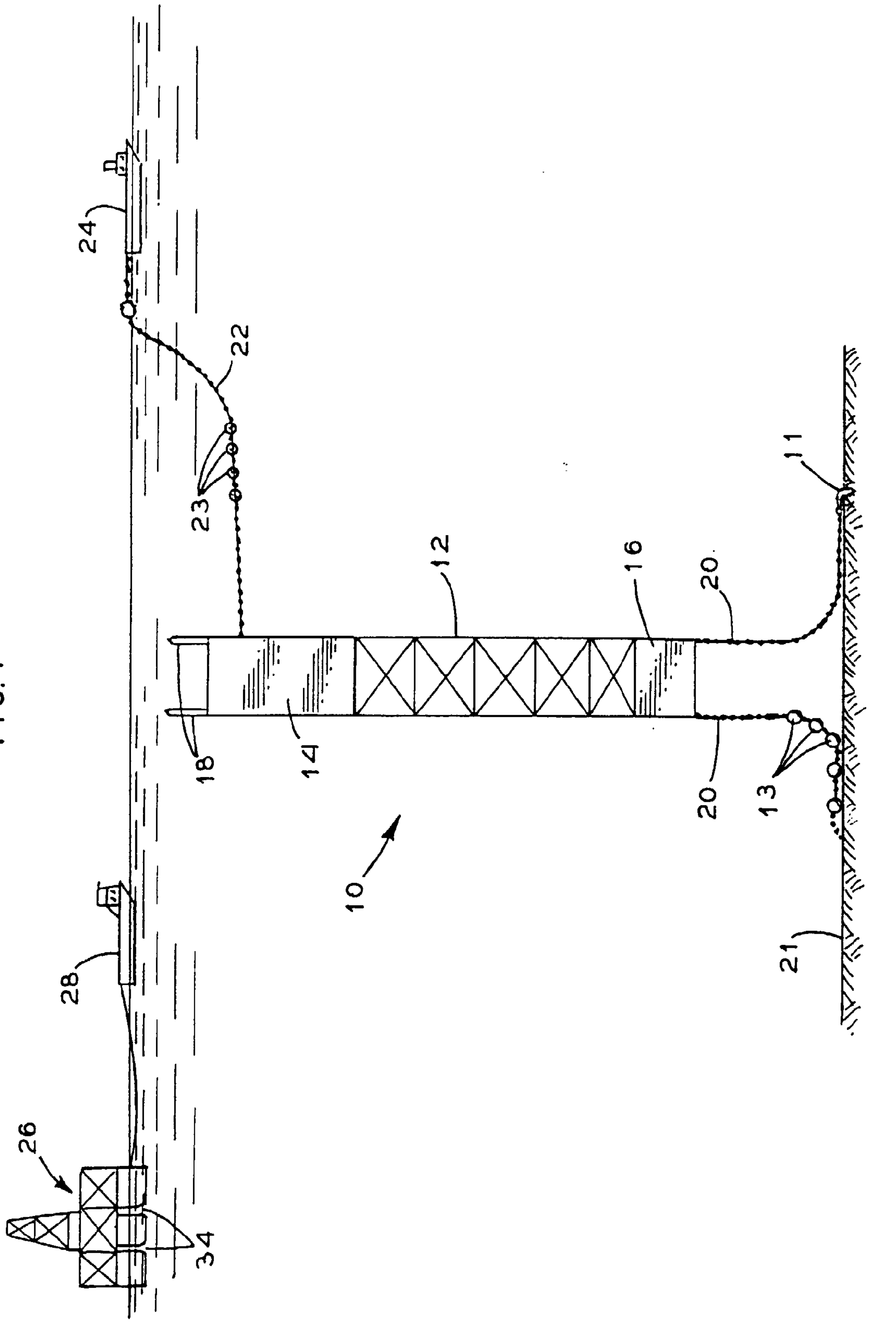

FIG. 1

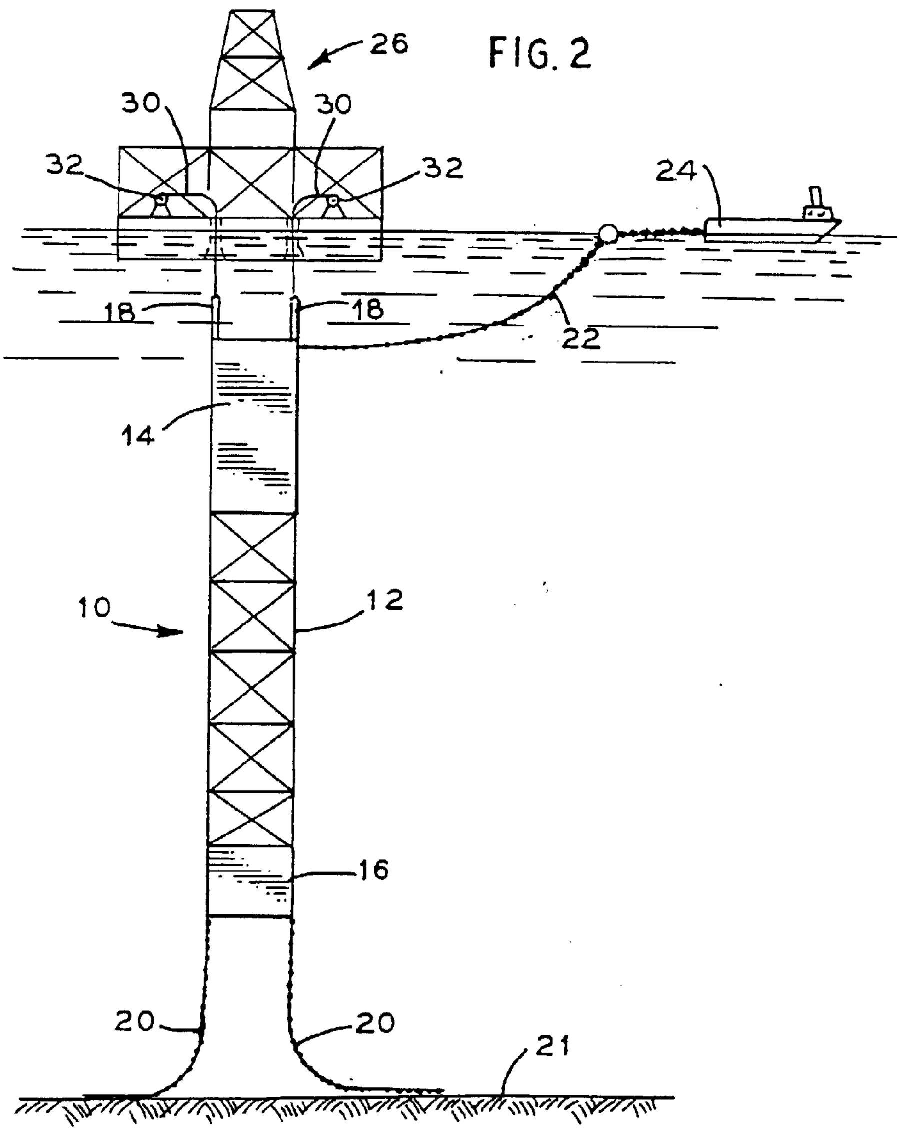
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FIG. 2

FIG. 3

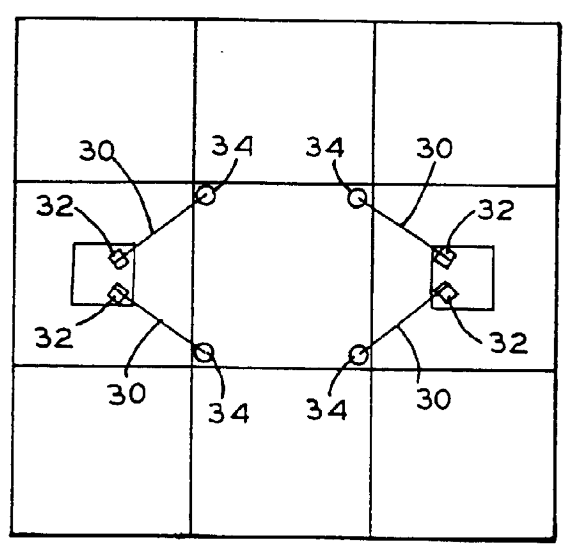
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FIG. 4

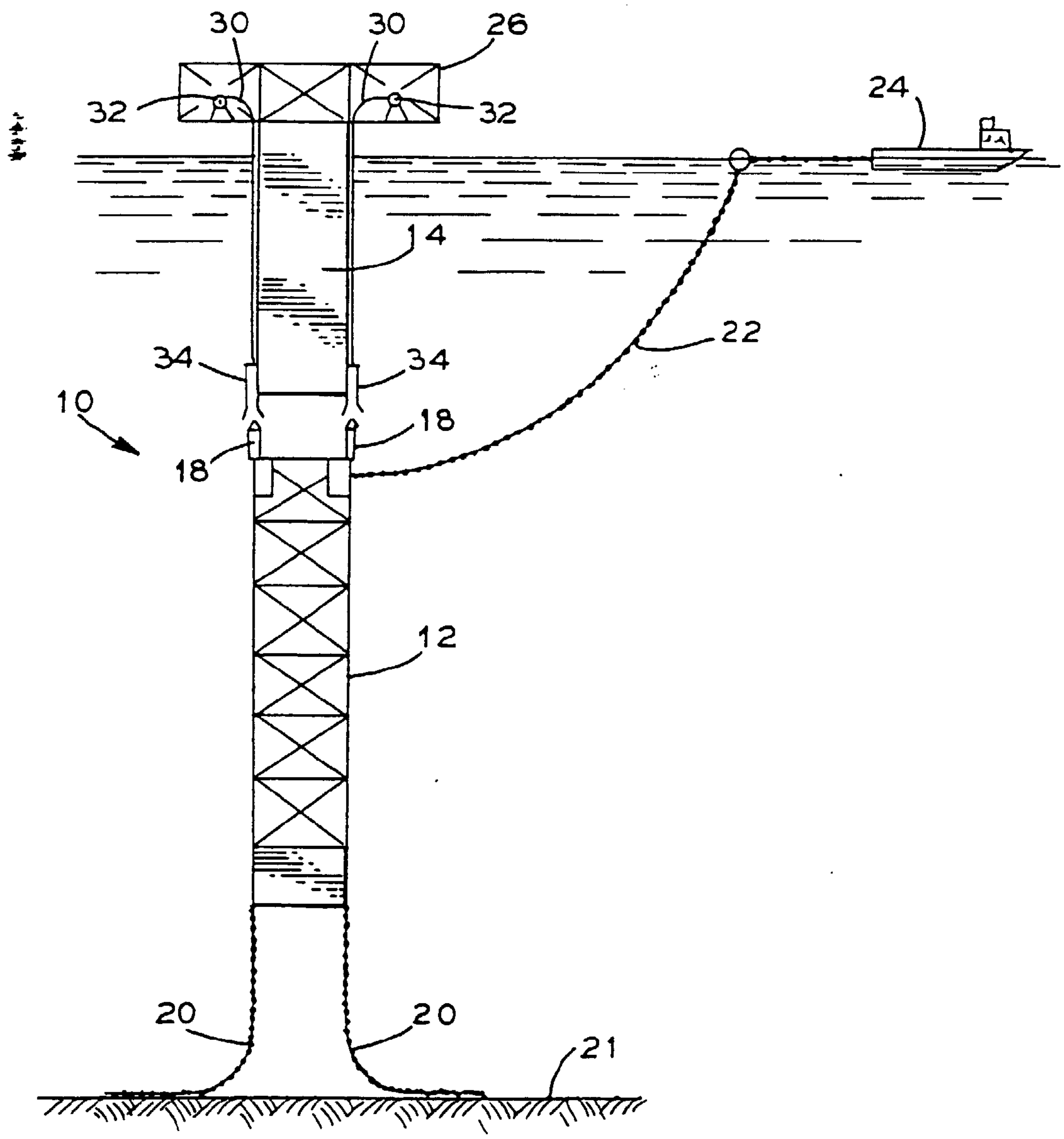

FIG.5

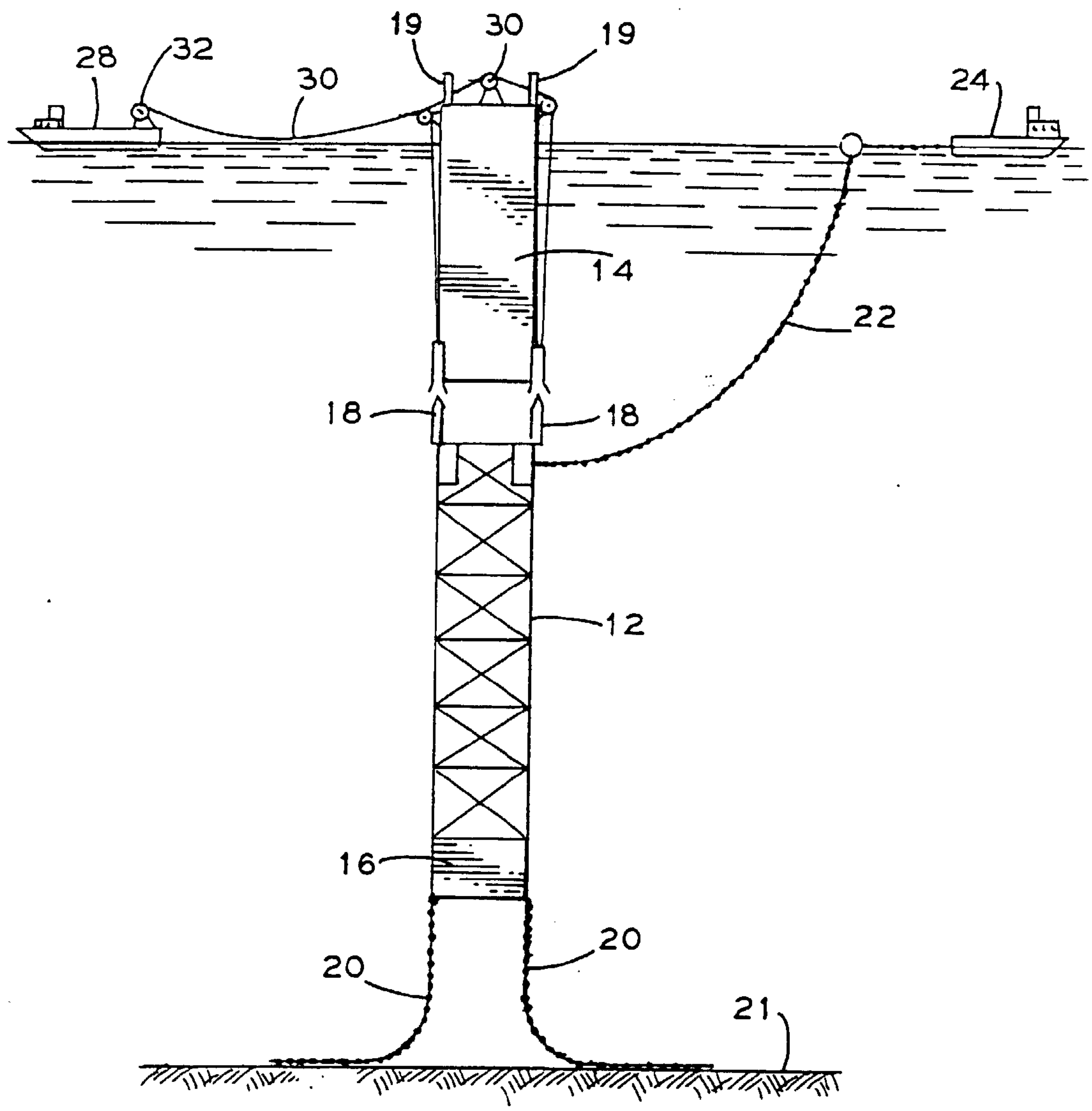

FIG. 6

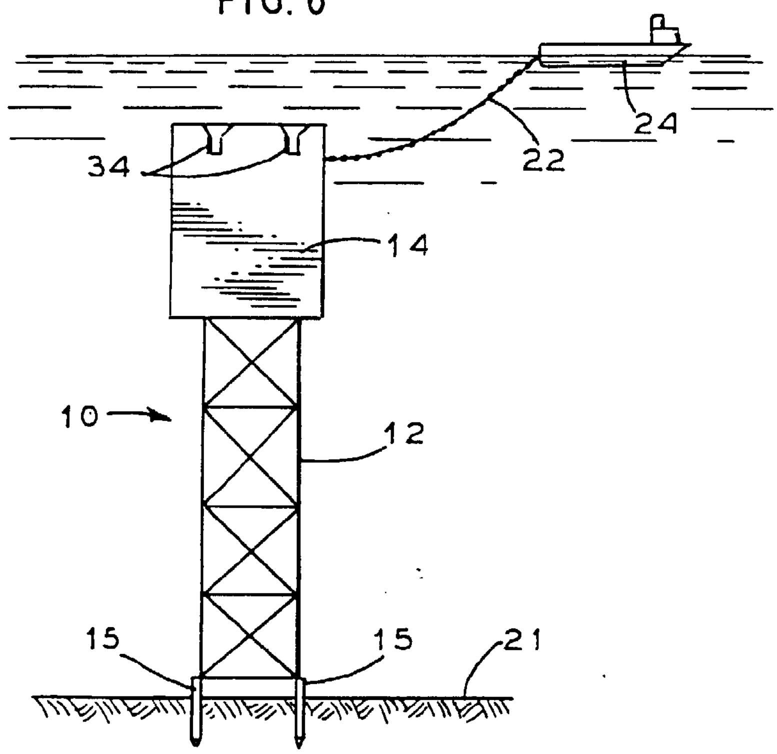

FIG. 7

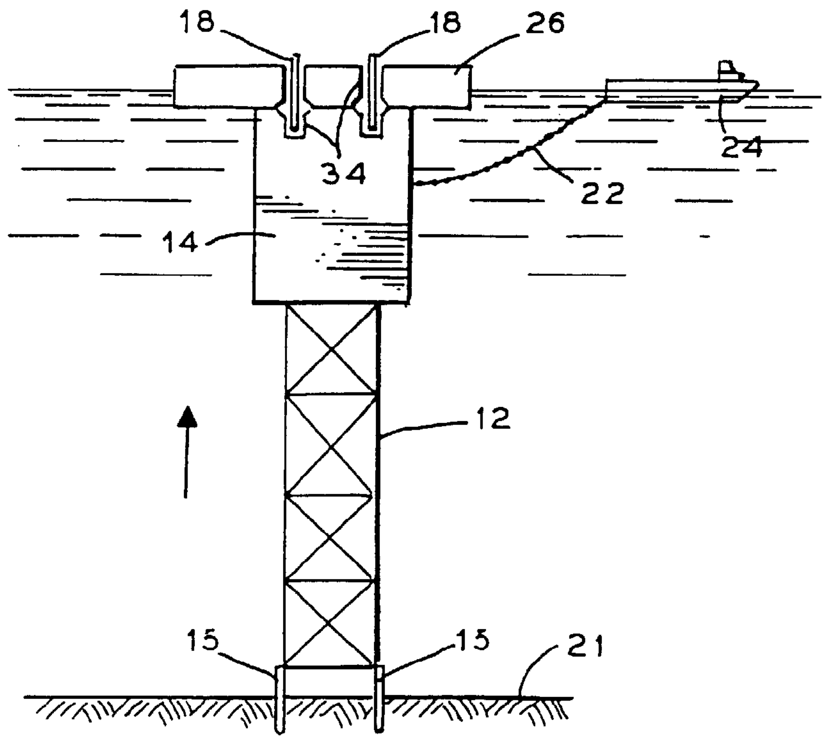

FIG. 8

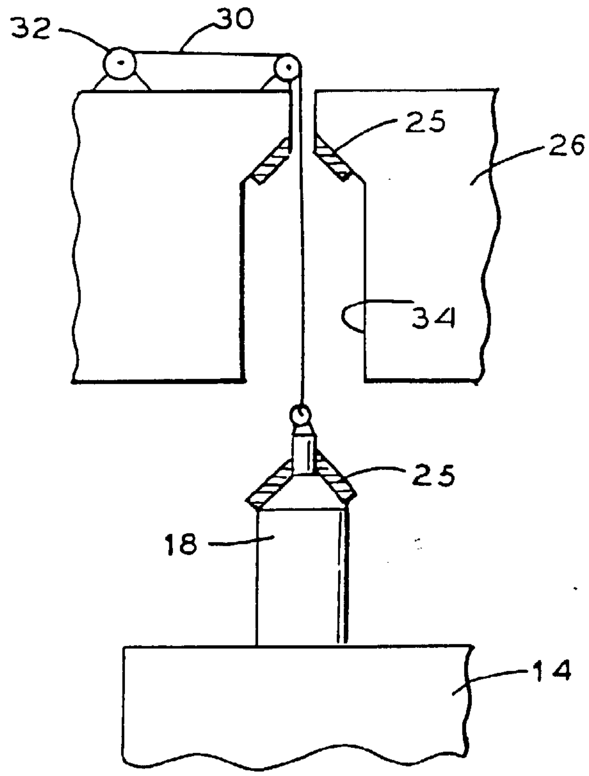

FIG. 9

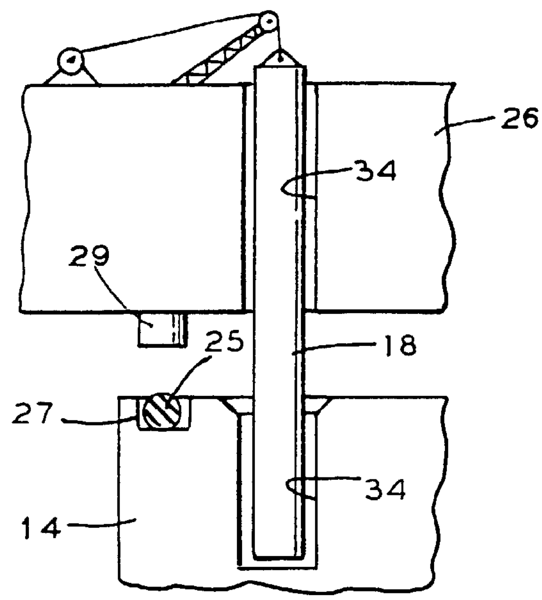

FIG.10

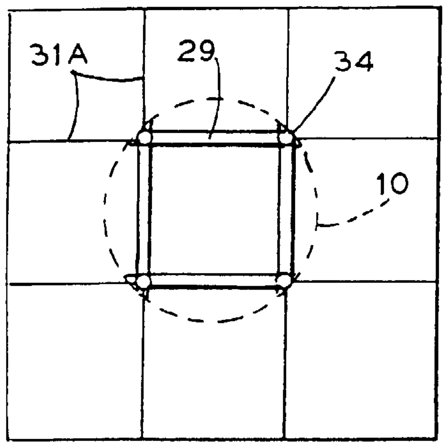

FIG.11

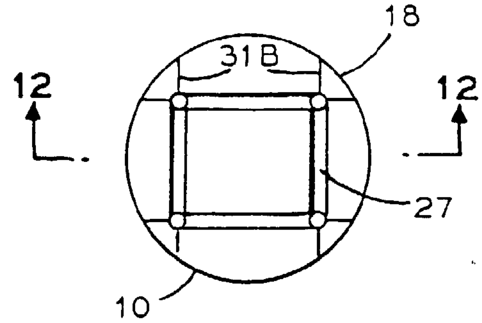

FIG.12

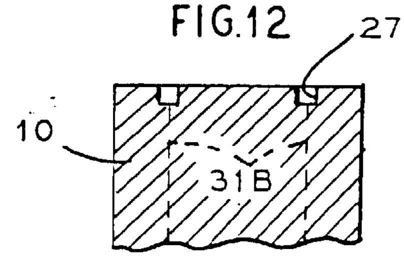

FIG.15

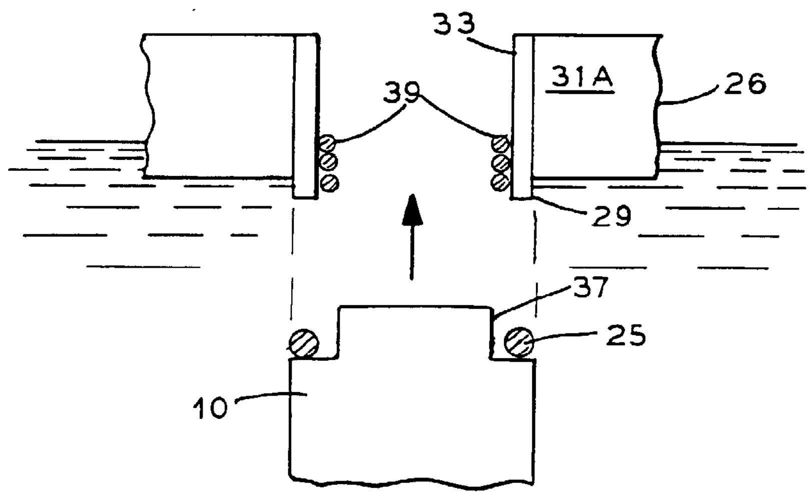

FIG.13

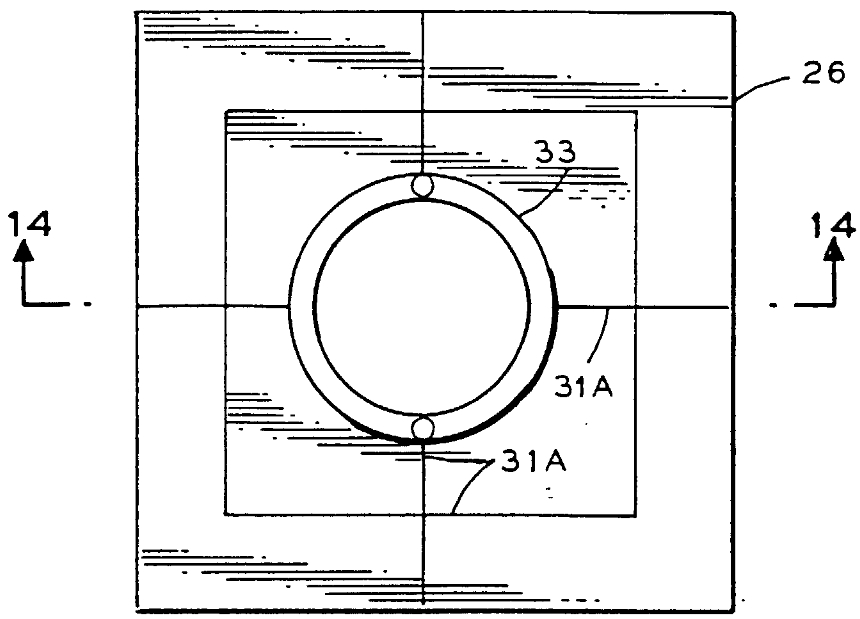

FIG.14

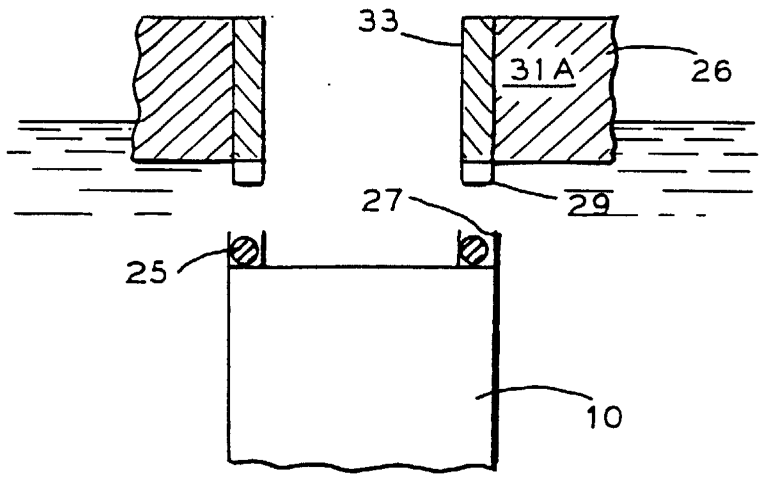

FIG.16

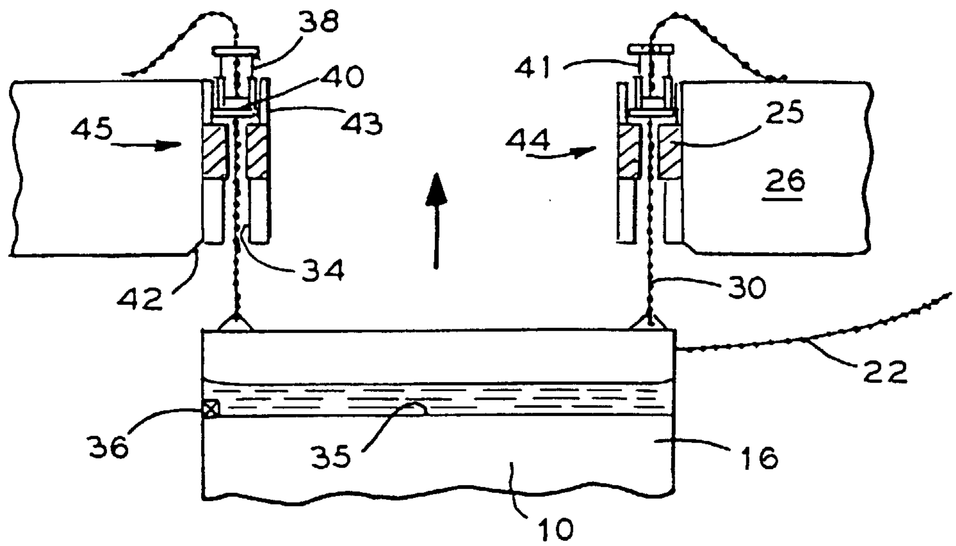

FIG.17