

[54] TENSION LEG OFFSHORE MARINE APPARATUS

[75] Inventor: Edward E. Horton, Portuguese Bend, Calif.

[73] Assignee: Deep Oil Technology, Inc., Long Beach, Calif.

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Related U.S. Application Data

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[52] U.S. Cl. 114/0.5 D, 61/46.5

[51] Int. Cl. B63b 35/44

[58] Field of Search 114/0.5 D, 0.5 R, 114/230; 61/46.5; 9/8 P

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Primary Examiner—Milton Buchler

Assistant Examiner—E. R. Kazenske

Attorney—Miketta, Glenn, Poms & Smith

[57]

ABSTRACT

An offshore mobile wave transparent marine apparatus constructed and arranged to be towed at a relatively rapid rate, stable and steady when anchored at a well site, and held by at least two virtually vertical mooring lines under selected tension. A marine apparatus having vertical buoyant columns related in size and location to horizontal buoyant members and designed for selected ocean and weather conditions, such as wave periods and height, whereby vertical forces acting on submerged substantially horizontal members and the vertical forces acting on the vertical members are offset and virtually canceled. Tensioned mooring means are held by restraint means located below the center of buoyancy of the apparatus for providing a low center of roll.

15 Claims, 9 Drawing Figures

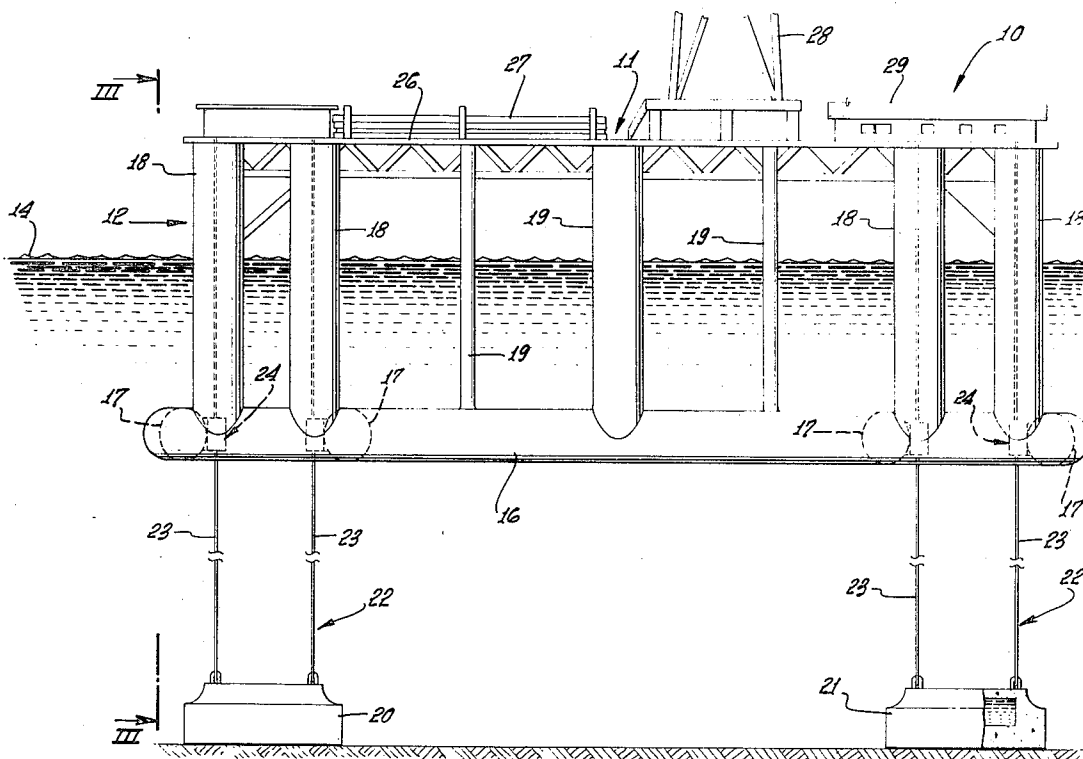


FIG. 1a.

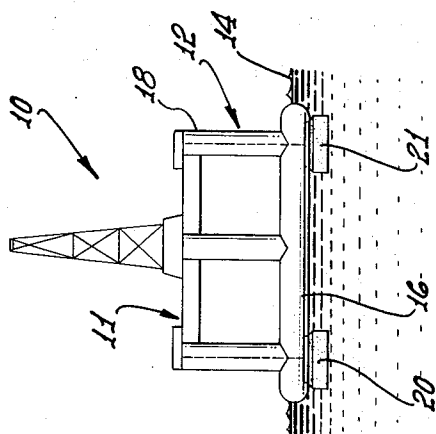


FIG. 1b.

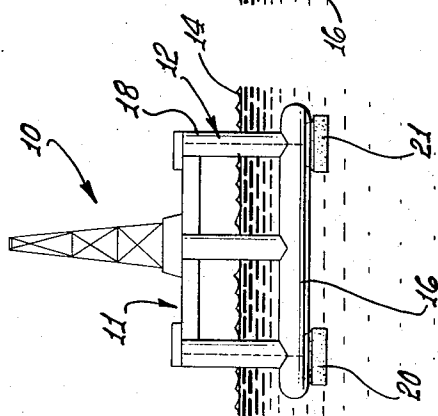


FIG. 1c.

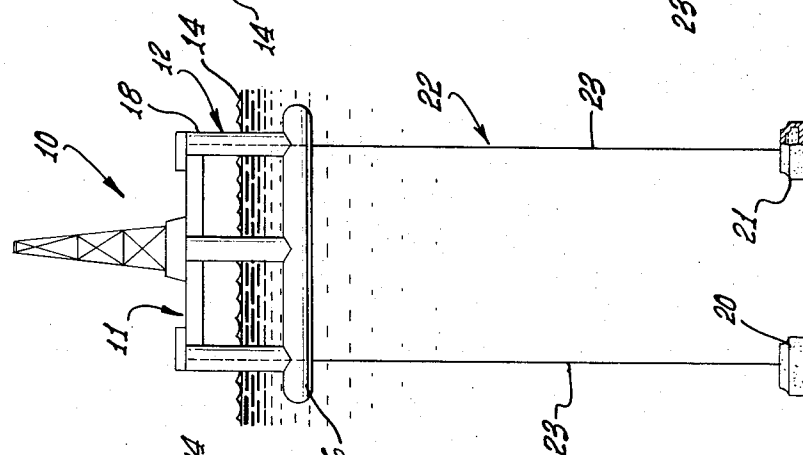
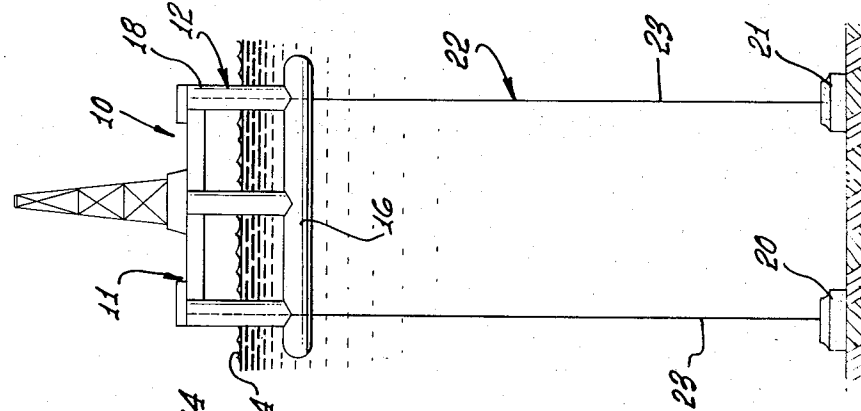
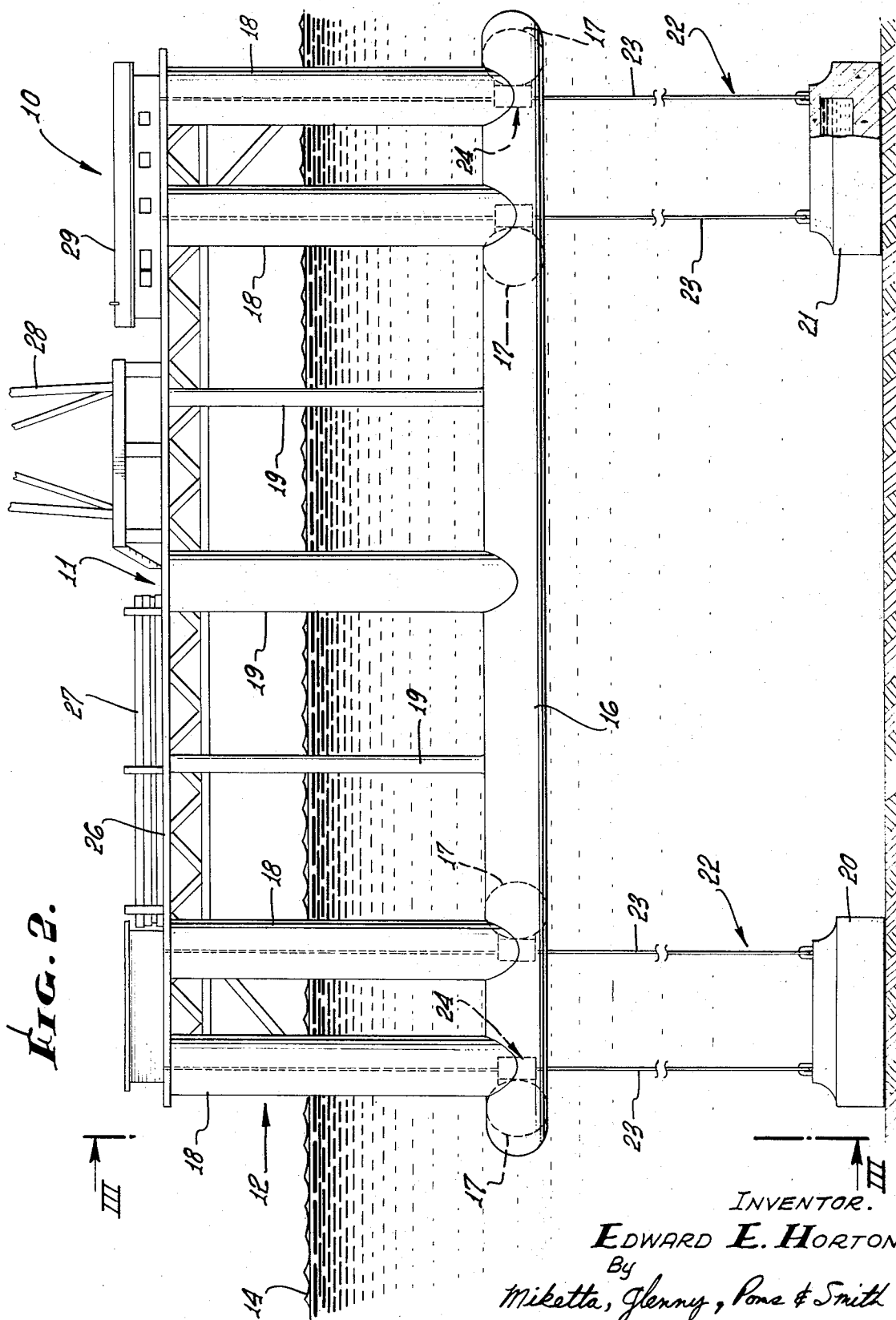


FIG. 1d.



INVENTOR
EDWARD E. HORTON

By
Miketta, Glenn, Poma & Smith
ATTORNEYS.



INVENTOR.
EDWARD E. HORTON
 By
Miketta, Glenn, Pons & Smith
 ATTORNEYS.

FIG. 3.

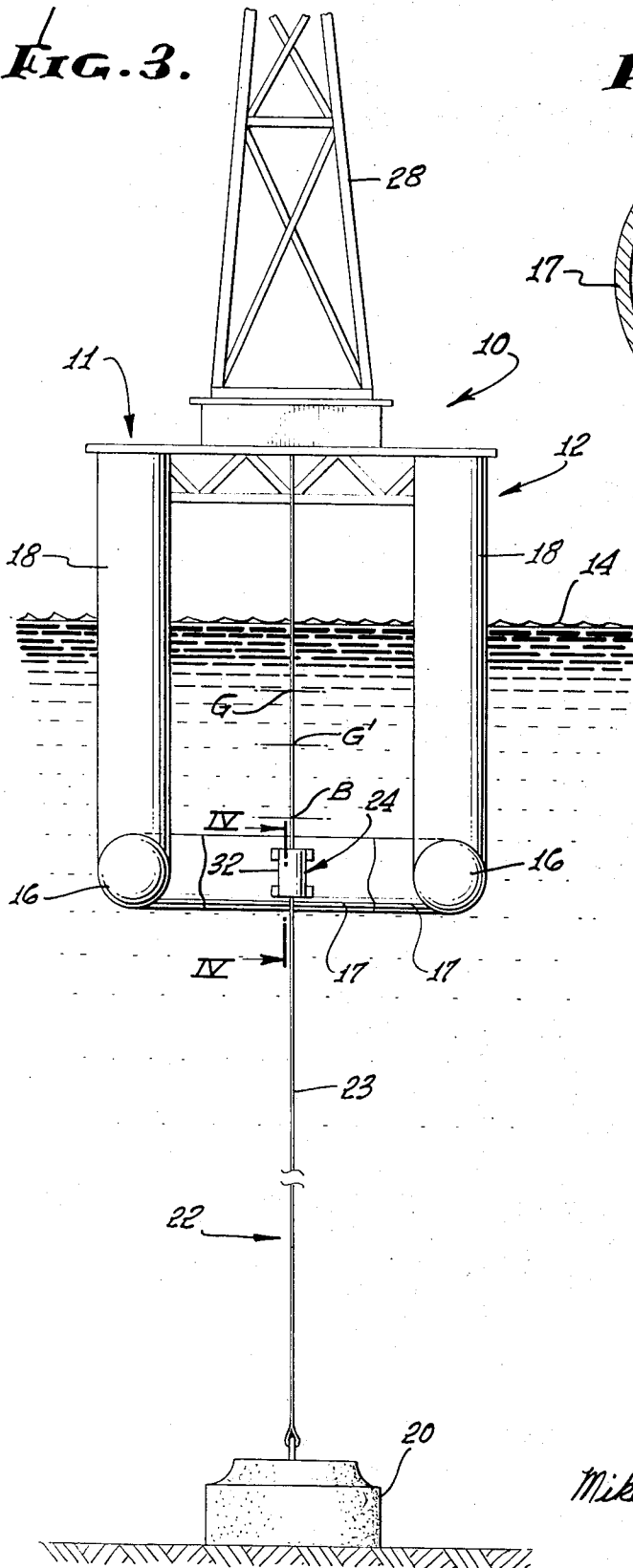
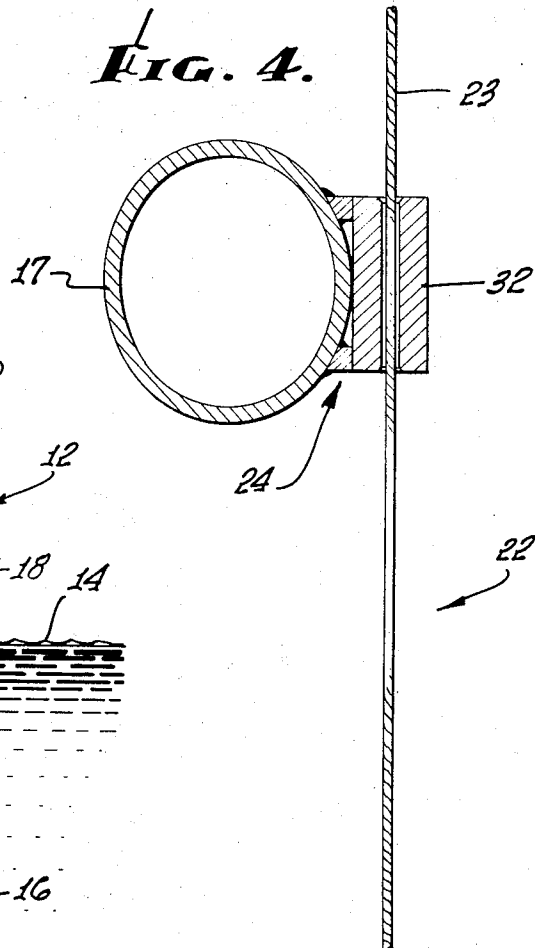


FIG. 4.



INVENTOR.
EDWARD E. HORTON

By
Miketta, Glenn, Pons & Smith
ATTORNEYS.

FIG. 6.

TENSION LEG PLATFORM
CABLE 2

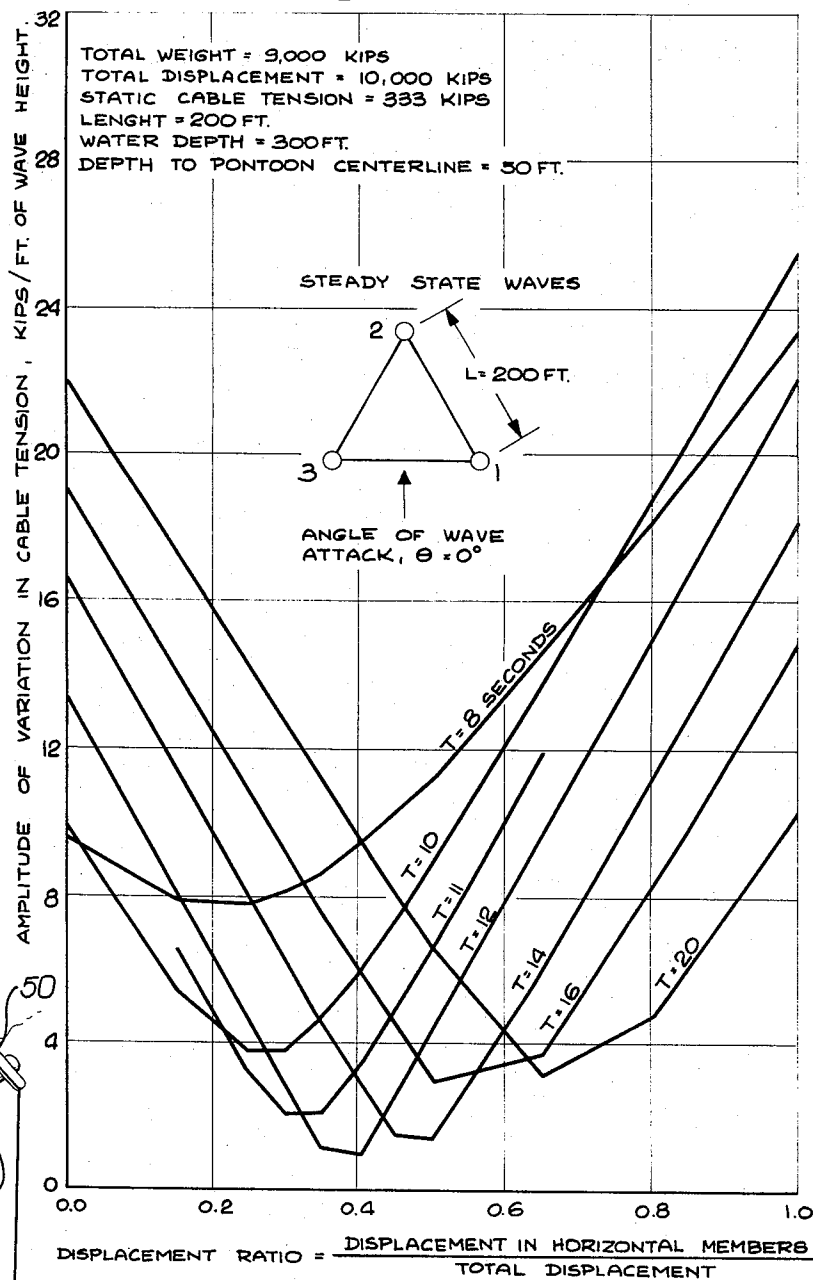
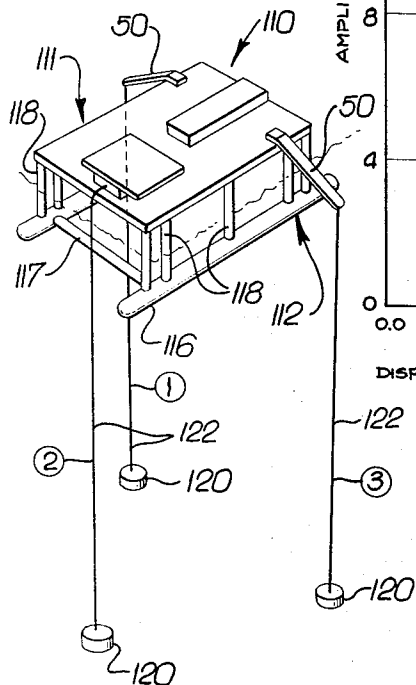


FIG. 5.



INVENTOR.
EDWARD E. HORTON

By

Miketta, Glenn, Pome & Smith
ATTORNEYS.

TENSION LEG OFFSHORE MARINE APPARATUS

Related Applications

This application is a continuation-in-part application of Ser. No. 821,275 filed May 2, 1969 entitled "Two Point Tension Leg Offshore Marine Apparatus" which is being abandoned in favor of this present application.

Background of the Invention

Prior proposed offshore well platform means have included various designs of structures to facilitate mobility and anchoring at a selected well or working site. Such prior proposed platform means have included several disadvantages some of which are: a construction having a relatively wide beam to accommodate a large amount of well equipment, rigs and other facilities necessary for an offshore well operation; a marine construction on which water transparency was limited thereby creating stability problems; and mooring or anchoring such floating platform means by various systems of anchor lines, counterweights, and structural support legs. Such constructions which employed substantially vertically tensioned mooring lines, such as Knapp U.S. Pat. No. 3,154,039, became excessively unstable and tiltable upon the breaking of one of the mooring lines. The plan or configuration of such prior proposed platforms have usually been of relatively wide beam and have included triangular, rectangular, hexagonal and other polygonal configurations which, except for the rectangular configuration, were relatively difficult and unseaworthy for towing. When such platforms carried partially air-filled anchors during towing, such platforms became unstable in the event air was lost in the anchors. Towing speed for such prior proposed offshore platforms was quite slow, for example about two knots. In addition to towing difficulties, the wideness of beam of such platforms prohibited passage through waterways of canals and thus their use was restricted to relatively local geographical ocean areas.

Such prior proposed offshore platforms also included relatively complex structure to reduce vertical oscillations, roll, and pitching of the platform at a well site. Vertically adjustable counterweights to lower center of gravity, swell compensators comprising cylinders vertically positionable in the water to compensate for vertical oscillations have been proposed (see U.S. Pat. No. 3,294,051). In all such prior proposed offshore platforms, the platform has been secured in place by a plurality of mooring lines, that is, three or more depending upon the polygonal configuration of the platform. In some instances as in Knapp U.S. Pat. No. 3,154,039, the mooring system served as platform tension members or lines.

The present invention contemplates a novel offshore marine apparatus which obviates many of the disadvantages of prior proposed structures and includes advantages not achieved by such prior structures by reason of a novel arrangement of a platform means, submersible buoyant supporting structure for the platform means, and a mooring system providing tension legs for the platform means, an apparent low center of gravity, and a low center of roll. Such a contemplated offshore marine apparatus may be provided with relatively narrow beam sufficient so as to facilitate navigation and to readily pass through principal canals, such as the Panama Canal.

The primary object of the present invention is therefore to disclose and provide a novel offshore marine apparatus readily adaptable for exploratory, drilling, and workover well operations.

An object of the present invention is to provide an offshore marine apparatus for well operations having relatively high mobility and desirable steadiness and stability under various conditions of weather and ocean currents.

Another object of the present invention is to disclose and provide an offshore marine apparatus for well operations utilizing a tension leg mooring system having two or more tension legs and of stable steady characteristics.

A further object of the present invention is to disclose and provide an offshore marine apparatus for well operations wherein the apparatus is provided with stabilizing vertical buoyant columns so constructed and arranged with respect to the submersible horizontal buoyant means that vertical force components acting upon the apparatus are offset against each other and vertical oscillations are minimized.

A still further object of the present invention is to disclose and provide an offshore marine apparatus for well operations utilizing, in one example, a two point tension leg mooring system wherein restraint means are provided in the vicinity of the submersible buoyant means to provide a low center of roll for the apparatus.

An important object of the present invention is to disclose and provide a novel stable and steady marine apparatus constructed so that vertical force components arising out of displacement of the apparatus relative to wave motions are virtually completely offset against vertical force components caused by acceleration of wave particles acting on submerged horizontal members and thereby minimizing cyclic stresses on the tension leg mooring system and enhancing steadiness of the apparatus.

The present invention also contemplates a tension leg platform having two or more tension legs connecting anchor means to the platform means, and a submersible buoyant means located at a depth within the influence of wave action, the submersible buoyant means including horizontal and vertical buoyant members in which the displacement ratio of the horizontal members with respect to the total displacement being in the order of 0.30 to 0.60 whereby amplitude of variation of tension forces in the tension legs is minimized.

It is another object of the invention to provide a tension leg platform including parallel submersible horizontal buoyant members wherein at least three tension legs are provided, two of such legs being connected to a platform through sidewardly extending retractable boom members and wherein the parallel members provide a sufficiently narrow beam to permit increased mobility and passage through canal systems.

Other objects of the invention include the provision of a versatile tension leg type offshore platform readily adapted to meet the many and varied requirements for offshore well operations including mobility, low cost, rapid installation in locations of varying depth, and steadiness and stability during widely varying weather and wave conditions.

Various other objects and advantages of the present invention will be readily apparent from the following description of the drawings in which exemplary embodiments of the invention are shown.

IN THE DRAWINGS:

FIGS. 1a to 1d inclusive, show one embodiment of an offshore marine apparatus embodying this invention; FIG. 1a showing the apparatus in towing condition; FIG. 1b in semi-submersed condition prior to lowering the anchors; FIG. 1c in semi-submersed condition with the anchors being lowered; and FIG. 1d in semi-submersed operating condition with the anchors set on the ocean bottom;

FIG. 2 is an enlarged side elevational view of the apparatus shown in FIG. 1d;

FIG. 3 is an end view of the apparatus shown in FIG. 2, the view being taken from the plane indicated by line III—III of FIG. 2;

FIG. 4 is a vertical sectional view taken in the plane indicated by line IV—IV of FIG. 3.

FIG. 5 is a perspective view of another embodiment of this invention.

FIG. 6 is a chart showing an exemplary relationship of variation in cable tension with respect to displacement ratio of the submerged buoyant members and wave period of an apparatus embodying this invention.

Referring to the embodiment of this invention shown in FIGS. 1—4, a marine apparatus embodying this invention is generally indicated at 10 and comprises a platform means 11 and submersible buoyant means 12 for supporting the platform means at a selected distance above an ocean surface 14. Supporting means 12 includes a pair of parallel longitudinally extending submersible pontoons or horizontal buoyant members 16, transverse horizontal buoyant members 17 interconnecting ends of members 16, and vertical column buoyant members 18. Platform means 11 may also be supported from the supporting means 12 by a plurality of selectively arranged structural legs or columns 19. At a well site, apparatus 10 may be secured to two spaced anchor means 20, 21 to which are attached two mooring means 22 which extend virtually vertically upwardly to platform means 10 where they may be connected to suitable mooring line tensioning means (not shown). The mooring lines 22 pass through a restraint means 24 provided in this example on transverse buoyant members 17, the restraint means locating the center of roll of apparatus 10. As best seen in FIG. 3, anchor means 20, 21, mooring means 22, restraint means 24 and the center of buoyancy B and center of gravity G of the apparatus when in normal position lie in a vertical plane passing through the longitudinal axis of apparatus 10.

Platform means 11 may be of any suitable structure including a platform deck 26 which may carry various and sundry well tools and equipment required for drilling or working over a well hole, such as the schematically illustrated pipe rack 27, derrick 28 and building 29. Platform means 11 has a relatively narrow beam or width as compared to its length. In this respect construction of apparatus 10 is such that its beam will not exceed the width of canals or water passageways through which it may be desired to float apparatus 10.

Supporting means 12 for platform means 11 may comprise a pair of parallel spaced apart longitudinally extending horizontal pontoons or buoyant members 16 normally submersible beneath longitudinal side portions of platform means 11 and not exceeding in width the beam of platform means 11. Buoyant members 16 and 17 may be cylindrical in cross-sectional configura-

tion for low cost construction or may be elliptical in cross-sectional configuration to obtain the advantages described in my copending application Ser. No. 797,121 and to augment the stability and steadiness of the apparatus. Buoyant members 16 and 17 provide sufficient buoyant capacity to enable apparatus 10 to be floated at the ocean surface in a towing position as later described.

The vertical column buoyant members 18 are carried by ends of buoyant member 16 and extend upwardly to the opposed corners of platform means 11. Each buoyant column 18 is provided with a cross-sectional area which is uniform throughout the length of the column, the area being related to several factors as hereinafter described in order to provide a stable marine apparatus.

Structural legs 19 extend between horizontal longitudinal buoyant member 16 and platform means 11 in selected spaced relationship to provide necessary structural strength to support platform means 11 from member 16. The exemplary arrangement of legs 19 and column members 18 in the present apparatus provide high water transparency for apparatus 10.

Anchor means 21 may be arranged to be carried between buoyant members 16 adjacent transverse members 17 when apparatus 10 is to be towed, the anchor means being related to buoyant members 17 so as to reduce drag forces caused by transverse members 17. Anchor means 21 may be of suitable construction and when transportable may include a suitable outer casing or shell adapted to contain a selected amount of anchor material or ballast and a compartment for introducing and ejecting therefrom water so as to permit the anchors to be fixed at a selected site on the ocean floor and to be lifted therefrom for movement to another well site. It will be understood that permanent anchors may be located at a selected well site and connected with apparatus 10.

Each mooring means 22 may include one or more cables 23 at each end of apparatus 10, any arrangement of more than one cable being cooperably connected with support means 12 so as to function effectively as a single mooring means at one end of apparatus 10. Each mooring means 22 may be connected to anchor means 21 in well known manner and extends upwardly in a longitudinal vertical plane defined by the two mooring means 22 at opposite ends of the apparatus, the plane normally passing through the center of gravity of apparatus 10. Mooring means 22 may comprise suitable lines, chains or cables having their upper ends connected to associated anchor or mooring line tensioning means (not shown) carried by platform means 11.

Restraint means 24 for each of lines 23 may comprise a hawser pipe 32 carried on transverse buoyant member 17 at its transverse center portion adjacent the bottom thereof. Hawser pipes 32 lie in the same vertical longitudinal plane as mooring means 22, center of buoyancy at B, and center of gravity G of apparatus 10 when it is in normal position. Hawser pipes 32 restrain lateral movement of anchor lines 23 and thereby provide a means for establishing a center of roll R of apparatus 10 which lies a substantial distance below the center of buoyancy B and center of gravity G of the apparatus. Restraint means 24 may comprise other devices for holding, securing or restraining the mooring means 22 at a selected depth beneath the ocean surface and

in the general zone of buoyant members 16 and 17. For example, restraint means 24 may comprise a vertically adjustable device cooperable to restrain mooring lines 23 at different points along their length so that the center of roll of apparatus 10 may be varied with respect to the vertical position of buoyant member 16, thereby improving the steadiness of the apparatus 10.

It will be understood that suitable ballast pumping equipment, pipes, and valves are connected with buoyant members 16, 17 and 18 as well as anchor means 20 and 21 for supplying water to and evacuating water from the buoyant members and anchor means. Such ballasting systems and equipment are well known and therefore are not shown or described in this application for purposes of brevity.

In towing position of apparatus 10, ballast in buoyant members 16, 17 and 18 and anchor members 20 and 21 is adjusted so that the buoyant members 16 and 17 support the apparatus 10 at a selected towing position, buoyant members 16, 17 being adjacent to the water surface in the floating condition. Anchor means 20, 21 are evacuated and may be self-supporting when carried in towing position between buoyant members 16 and adjacent buoyant members 17 (FIG. 1a). The relatively long, narrow construction of apparatus 10 facilitates navigation and towing speeds may be in the order of 6 to 8 knots.

At a well or working site, the long, narrow construction of apparatus 10 generally facilitates location of the apparatus with respect to a subsea wellhead system or drilling templates. The drilling rig carried on the platform means may be readily shifted along the longitudinal axis of apparatus 10 and thus simplifies positioning of the apparatus in relation to the subsea installation. When the apparatus 10 is located in selected position over a subsea wellhead or site, ballast may be introduced into buoyant members 16, 17 and 18 until the apparatus 10 is semi-submerged to a selected depth (FIG. 1b). Anchor means 20, 21 may then be lowered by flooding compartments provided in the anchor means until the anchors are in desired position on the ocean floor (FIGS. 1c, 1d). When they are so located, the anchor means may then be flooded or ballasted to their fullest extent to develop maximum anchor forces. During submerging of apparatus 10, it should be noted that the water plane passes through the vertical stabilizing columns 18 during the anchoring operation and thereby provides the apparatus with increased steadiness during the submergence operation and non-responsiveness to heaving. As the apparatus 10 is lowered into semi-submerged position, it is guided downwardly along the mooring lines 22, which are restrained against lateral movement with respect to the buoyant members by the restraint means 24.

After anchoring at the selected depth, the mooring lines 22 may be tensioned so that apparatus 10 is held in position by the two point tension leg system described above. Tension forces imparted to mooring lines 22 are of such magnitude that the mooring lines 22 will not become slack under the heaviest expected sea conditions and under variations in loading of platform 11. The tension forces in mooring lines 22 create an effective lower center of gravity of apparatus 10 which lies below the normal center of gravity indicated at G, the apparent center of gravity being indicated at G'.

In the semi-submersible working position of apparatus 10, it is important to note that the mooring lines 22 pass through the restraint means 24 at a lower portion of the buoyant member 17 and, since the apparatus is anchored by means of a two point tension leg system, the very low location of restraint means 24 provides a low center of roll located below the center of buoyancy of apparatus 10 and thereby contributes to the stability of apparatus 10.

Stabilizing vertical columns 18 are constructed and arranged in spaced relationship with respect to the buoyancy characteristics of the horizontal buoyant members 16 and 17 to provide a long period of roll, such as 25 seconds. Specific ocean conditions are considered in the design of stabilizing columns 18. Usual wave periods are in the order of from 5 to 25 seconds, and the provision of a long period for the semi-submersible apparatus 10 provides a structure which is relatively non-responsive to wave action and in which cyclic stresses on the anchor lines are minimized. It will be understood that when the crest of a wave passes over buoyant members 16 and 17, the acceleration of water particles acting on the effective horizontal surface components of submerged horizontal member 16 and 17 develop a downwardly directed vertical force component acting against said horizontal members. At the same time, as the crest of the wave passes through apparatus 10, upwardly directed buoyant forces are increased by the further displacement of the stabilizing columns 18 in the water. The downwardly acting forces and the upwardly acting forces are oppositely directed and substantially tend to offset and cancel each other because of the correlation of the size of stabilizing columns with the horizontal members 16 and 17. Vertical forces caused by wave motion acting upon apparatus 10 are thereby virtually offset and cancelled thereby reducing the magnitude of the cyclic loads on the tension members caused by the wave forces. It will be understood that the exemplary horizontal members 16 and 17 present cylindrical surfaces to the water and with respect to the direction of the vertical tension force and the vertical force components of water particles in wave motion, the cylindrical surfaces present effective horizontal surface components against which the vertical force components of the wave particles act to provide a resultant vertically directed force.

It will be apparent to those familiar with hydrodynamics that the degree or amount of cancellation will be dependent upon the wave period. For example, if the wave period were very long, the upward force from the added displacement would be large relative to the downward force from particle acceleration and conversely, if the wave period were very short, the downward force from acceleration would be large in relation to the upward force resulting from displacement.

In an example of this invention, it may be contemplated that the water planes of the vertical columns 18 be sized relative to the horizontal members such that the net vertical force is minimized for those wave periods which contain most of the wave energy during severe storms, such wave periods being from approximately 8 seconds to 20 seconds. Stability and steadiness of apparatus 10 are thus enhanced by the stabilizing columns 18 by the provision of the selected water plane area where the columns pass through the surface of the water.

Apparatus 10 with the two point tension leg mooring arrangement provides additional advantages and safety for the apparatus in the event one of the mooring lines should part. When this occurs at one end of the relatively long elongated narrow beam platform, the apparatus would rise to a new level at the end at which the cable had parted and would be inclined at an angle of approximately 10° to 15°. Apparatus 10 is then held by only one mooring or anchor line to head into the sea and assume a most favorable position. The stabilizing columns are designed so that the volume and area thereof will contribute to the stability of the apparatus under such conditions.

In the embodiment of the invention shown in FIG. 5, similar parts will be given like reference numerals plus 100. Apparatus 110 may comprise a platform supported by a submerged buoyant means 112 which is held submerged by anchor means 120 having in this example a triangular pattern. Tension leg end and side mooring lines 122 are connected to the platform means 111, end mooring line 122 lying in a vertical plane which generally longitudinally bisects apparatus 110. Side mooring lines 122 may be connected to platform means 111 through laterally extending boom members 50. Boom members 50 are retractably mounted on platform means 111 so that they may be swung over the top deck of platform means 111 while apparatus 110 is in transit between well sites. Means for applying tension to the mooring lines 122 are not shown and are well known.

Submerged buoyant means 112 includes horizontal buoyant members 116 and 117, buoyant members 116 being spaced apart in parallel horizontal relation and may have a narrow overall beam such as described with respect to the spacing of horizontal buoyant members 16 in the prior embodiment of the invention. Parallel longitudinally extending buoyant members 116 are interconnected by transverse buoyant members 117. Horizontal buoyant members 116 and 117 may be cylindrical in cross-section or may embody the oval cross-section described in my aforesaid co-pending application Ser. No. 797,121.

Vertical buoyant members 118 may be generally arranged as shown in FIG. 2 and may comprise vertically extending hollow buoyant columns which project above the water plane and which support the platform means 111.

The stability and steadiness of apparatus 110 includes those factors described above with respect to apparatus 10. It will be further understood that the inventive features of cancellation of vertical forces in a tension leg platform are not limited to platforms having two or three tension legs or a platform supported from submersible buoyant members having a shape or configuration of parallel or triangular horizontal buoyant members. To further illustrate the inventive features, FIG. 6 shows the reduction and minimization of the amplitude of variation in cable tension by employing horizontal members of selected buoyancy as related to vertical buoyant column members of selected buoyancy and water plane area or as related to total displacement of buoyant supporting means, the type of platform upon which FIG. 6 is based being triangular and being specified as to weight, displacement, size, submerged depth, cable tension, etc. as indicated in FIG. 6. The curves shown in FIG. 6 indicate the vertical force cancellation for the specified platform; and such

curves are representative of the type of force cancellation embodied in apparatus 10 and 110. To facilitate description and for purposes of brevity the displacement and tension factors of the chart in FIG. 6 will be referenced to FIG. 5.

In FIG. 6 a tension leg platform is diagrammatically illustrated in which the wave angle of attack is normal to the side of the triangular mooring line pattern defined by side mooring lines 122 and further identified with respect to FIG. 6 as 1 and 3. The amplitude of variation in cable tension of line 122 or cable 2 is measured along the ordinate of the chart in terms of kips per foot of wave height, a kip being 1,000 pounds of deadweight. Displacement ratio, that is, the displacement of horizontal members 116 and 117 to the total displacement, that is, the displacement of horizontal members 116, 117 and vertical buoyant member 118 is measured along the abscissa of the chart. Curves are shown for steady-state waves having periods of from 8 to 20 seconds. In the example shown in FIG. 6, it will be apparent that for wave periods of from 10 to 20 seconds that amplitude of variation in cable tension is minimized to less than 4 kips per foot of wave height when the displacement ratio, as defined above, lies between 0.25 and 0.65 and that between 0.30 and 0.50 cyclic stressing of the mooring lines in tension is at a minimum for waves having periods from 11 through 16. It thus becomes apparent that a submersible buoyant means comprising horizontal and vertical buoyant members when made with a displacement ratio of between about 0.30 and 0.60 will minimize amplitude of variation in cable tension so that steadiness and stability of apparatus 110 is provided. It will be understood that the chart shown in FIG. 6 relates to tension characteristics of the end mooring line 122 or cable 2 which represents the most severe stress conditions placed on a cable tension leg in such an apparatus. In the embodiments of this invention, the displacement relationship of horizontal buoyant members and vertical buoyant members is similarly provided so that the minimal amplitude of variation in cable tension in lines 22 will also be achieved as described.

Installation of apparatus 110 at a well site is similar to that described for apparatus 10 and it would be particularly noticed that during the step of submerging the buoyant members that the platform is provided increased steadiness because of the passing of the water plane through the vertical columns during the anchoring operation.

The arrangement of stabilizing columns which produces a minimizing of resultant vertical forces on the buoyant members 16, 17, 116, 117 permits the apparatus 10, 110 to be operative at a higher level in its semi-submersed state for a given sea state. Further, the arrangement of low center of roll in the case of apparatus 10 and the lateral stability imparted by the sidewardly extended boom members in apparatus 110 also contributes to the capability of the apparatus to be operative at a higher level in the water. This results from the cancellation of vertical forces acting on the buoyant members and thereby permits the apparatus 10, 110 to be positioned further upwardly in the zone of wave action. Such higher semi-submersed level improves the general stability of apparatus 10, 110. Operability at such higher level also reduces the cost of apparatus 10, 110 since the buoyant members may be positioned at, for example, approximately 50 feet when the stabilizing

vertical columns 18, 118 have been properly sized and related to the overall displacement ratio as indicated in FIG. 6. It is understood that without stabilizing columns, the depth of operability of the buoyant members 16, 17, 116, 117 would be in the order of one hundred feet.

It will thus be readily apparent to those skilled in the art that a novel apparatus 10, 110 of semi-submersible type has been provided by the present invention, and that apparatus 10, 110 will not tend to move vertically in a sea because of the arrangement of stabilizing columns, the tensioned marine lines, and the relationship of the horizontal buoyant members 16, 17, 116, 117 to the stabilizing columns 18, 118. In addition, in towing position apparatus 10, 110 is capable of a significantly greater speed and may be readily designed with a narrow beam to permit the apparatus to pass through selected canals and channels. Thus, apparatus 10, 110 when adapted to carry and transport anchor means 20, 21, 120, facilitates exploratory drilling and later changing to development drilling, such as installation of a subsea well head.

All modifications and changes coming within the scope of the appended claims are embraced thereby.

I claim:

1. In a marine structure of high stability and relatively narrow beam adapted for use as a mobile platform for well operations, the combination of:

a platform means positionable a selected height above an ocean surface;

means supporting said platform means and including submersible buoyant means comprising at least a pair of longitudinally extending horizontally disposed spaced parallel buoyant members,

said support means at each end thereof including mooring line restraint means located in the space between said buoyant members;

an anchor adapted to be located on the ocean floor beneath each of said restraint means;

and a single tensioned mooring means extending vertically between said anchor and said restraint means at each end of said support means;

said restraint means providing a location for the center of roll of said platform means at about the depth of said horizontal buoyant members.

2. In a marine structure as stated in claim 1 wherein said means supporting the platform means includes vertical buoyant column means extending from said longitudinal buoyant members to said platform means and each column means having a selected water plane relative to the buoyancy of the horizontal buoyant members.

3. In a marine structure as stated in claim 1 wherein said restraint means for said mooring means is located below the center of buoyancy of the marine structure.

4. In a marine structure as stated in claim 2 wherein said vertical buoyant column means are selectively spaced along the length of said longitudinal horizontal buoyant members a distance related to expected length of ocean waves under a selected condition and said buoyant column means and said horizontal longitudinal buoyant members are so responsive to said waves whereby vertical force components resulting from wave action are virtually cancelled.

5. In a marine structure the combination of:

a platform means positionable in spaced relation to an ocean surface;

a pair of longitudinally extending parallel buoyant members disposed beneath longitudinal side portions of said platform means;

transverse submersible buoyant members interconnecting ends of said longitudinal buoyant members; vertical buoyant columns interconnecting said longitudinal buoyant members and said platform means in selected longitudinal spaced relation;

said platform means, submersible buoyant means, and vertical column buoyant means having a center of gravity;

an anchor adapted to be positioned on an ocean floor beneath each of said submersible transverse buoyant members and in a longitudinal vertical plane normally passing through said center of gravity;

a pair of mooring means for said marine structure; restraint means for each mooring means at said transverse buoyant member and at said vertical plane; said mooring means being under selected tension to provide an apparent center of gravity lower than the actual center of gravity;

said restraint means providing a center of roll for said marine structure at the approximate depth of said submersible horizontal buoyant members.

6. In a marine structure of steady stable characteristics, the combination of:

a platform means positionable a selected height above an ocean surface;

a plurality of anchor means on the ocean floor;

a plurality of tensioned mooring line means, each mooring line means being generally vertical and connected at one end to said anchor means and joined at its other end to said structure;

means supporting said platform means and including submersible buoyant means,

said submersible buoyant means being provided with a positive buoyancy exceeding the weight of the platform and its load to maintain tension in all of said mooring line means above a preselected tension force,

said submersible buoyant means comprising:

at least two elongated horizontal buoyant cylindrical members extending beneath said platform and a plurality of upstanding vertical buoyant cylindrical columns of uniform diameter throughout their length and providing a water plane at said ocean surface to maintain stability of the structure, said vertical buoyant columns extending between and connecting said horizontal buoyant members to said platform means,

said horizontal and vertical members being correlated in size and volume, the total displacement of the horizontal buoyant members with respect to the aggregate displacement of the horizontal and vertical buoyant members being in the ratio of 0.30 to 0.60 whereby action of waves having wave periods from about 8 to 20 seconds in respect of vertical force components is minimal to provide a virtually stable and steady platform means.

7. In a structure as stated in claim 6 wherein said plurality of mooring lines consists of two mooring lines, each of said mooring lines being at an opposite end of the platform means.

8. In a structure as stated in claim 6 wherein said plurality of mooring lines consists of three lines, one of said lines being at one end of said platform means, and

two of said lines being at opposite sides of the other end of said platform means.

9. In a structure as stated in claim 6 wherein said horizontal buoyant members include transversely extending parallel buoyant members.

10. In a structure as stated in claim 7 including restraining means cooperably engaged with each vertical mooring line adjacent said horizontal buoyant members for lowering and locating the center of roll of said structure at the depth of said horizontal buoyant members.

11. In a structure as stated in claim 6 including means for resisting roll of said platform means; said roll resisting means including

lateral restraint means cooperable with said tension mooring line means for displacing downwardly the normal center of roll of said marine structure to a location at approximately said horizontal buoyant means.

12. In a structure as stated in claim 11 wherein said lateral restraint means includes boom members extending sidewardly from one end of said platform and connected to said mooring tension lines.

13. In a marine structure of stable steady characteristics having a platform means adapted to be positioned over a plurality of anchor means on an ocean floor, the combination of:

tension leg means substantially vertically disposed and connected to said platform means;

means supporting said platform means above the ocean surface and including

submersible elongated horizontal buoyant members joined together and of a length and width having a selected displacement volume and adapted to be submerged to a depth within the influence of wave action;

vertically disposed buoyant column members of a length and width having a selected displacement volume and joined to said horizontal buoyant members at their bottom ends and to said platform means at their upper ends and having water planes of selected area throughout their height;

said horizontal and vertically disposed buoyant members being provided with a positive buoyancy exceeding the weight of the platform and its load to maintain tension in all of said tension leg means above a preselected tension force;

the displacement ratio between the horizontal members and the total displacement of said horizontal buoyant members and vertical buoyant members being in the order of 0.30 and 0.60 whereby vertical force components imparted to said submerged horizontal and vertical buoyant members by wave action are virtually offset and cancelled to minimize cyclic stressing of said tension leg means.

14. In a tension leg marine structure, the combination of:

a platform means adapted to be positioned in spaced relation to a water surface;

anchor means and tension mooring line means anchoring said platform means at a selected site, said tension mooring line means being connected at one end with said platform means;

said submersible buoyant means disposed below and supporting said platform means;

said submersible buoyant means being provided positive buoyancy exceeding the weight of the platform and its load to maintain tension in all of said mooring line means above a preselected tension force,

said submersible buoyant means including interjoined elongated horizontal cylindrical buoyant members parallel to said platform means and upstanding cylindrical buoyant members interconnecting said horizontal buoyant members and said platform means, said upstanding buoyant members being spaced apart a selected distance along said horizontal members;

said upstanding buoyant members having a water plane area at the water surface for maintaining a stability of said marine structure under towing, submergence, and moored conditions thereof;

said horizontal members having effective horizontal surface component areas reactive to motion of water particles to develop vertical force components;

the displacement of said horizontal buoyant members with respect to the total displacement of the marine structure being in the order of 0.30 to 0.60 for waves having periods ranging from about 8 to 20 seconds.

15. A tension leg marine apparatus comprising:

a floatable structure including a platform adapted to be supported above a water surface in a horizontal planar zone;

a submersible buoyant means supporting said platform and comprising

a plurality of submersible elongated horizontal buoyant members, each horizontal buoyant member being joined with an adjacent horizontal buoyant member,

said joined horizontal buoyant members providing a configuration in plan generally corresponding to the configuration of the platform;

a plurality of upstanding buoyant members in spaced relation around the configuration of the horizontal buoyant members and joined at their lower ends to said horizontal buoyant members extending through the water surface, and connected at their upper ends to said platform;

a plurality of anchor means in the ocean floor;

a tensioned mooring line for each anchor means, each line extending generally vertically between its anchor means and said floatable structure,

all of said mooring lines being held in tension above a selected tension force imparted thereto by positive buoyancy of the submersible buoyant means, the positive buoyant forces exceeding total weight of the platform and loading thereof;

the displacement of the horizontal buoyant members and horizontal portions thereof joining the lower ends of the upstanding buoyant members having a displacement ratio of 0.30 to 0.60 of the total displacement of the floatable structure whereby for wave periods of from about 8 to 20 vertical forces due to wave action are substantially neutralized by the variable buoyancy of said upstanding members and the acceleration of water particles acting on said horizontal and upstanding members.

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