United States Patent

[11] 3,577,946

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[54] **STABLE MARINE CONSTRUCTION**
10 Claims, 5 Drawing Figs.

[52] **U.S. Cl.** **114/0.5,** 61/46.5
[51] **Int. Cl.** **B63b 35/44,** E02b 17/00
[50] **Field of Search** .... 114/0.5 (D), 0.5, 121; 61/46.5

[56] **References Cited**

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2,939,291	6/1960	Schurman et al.	114/0.5(D)
3,082,608	3/1963	Daniell	114/0.5(D)X
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ABSTRACT: A marine construction and a mooring system therefor for supporting an above surface working platform wherein the marine construction comprises a stable determinate structure held by anchor means and by tension means interconnecting the anchor means and structure for positioning the marine structure a selected distance below the surface of the water. The submerged marine structure includes a plurality of main buoyant members forming a continuous peripheral buoyant means of selected cross-sectional configuration whereby cyclic stresses imparted to the structure and tension means by wave action are minimized and reduced. The submerged buoyant means also includes internal buoyant members symmetrically disposed with respect to the main buoyant members and arranged to interconnect corresponding portions of main members for enhancing stability of the construction under different conditions.

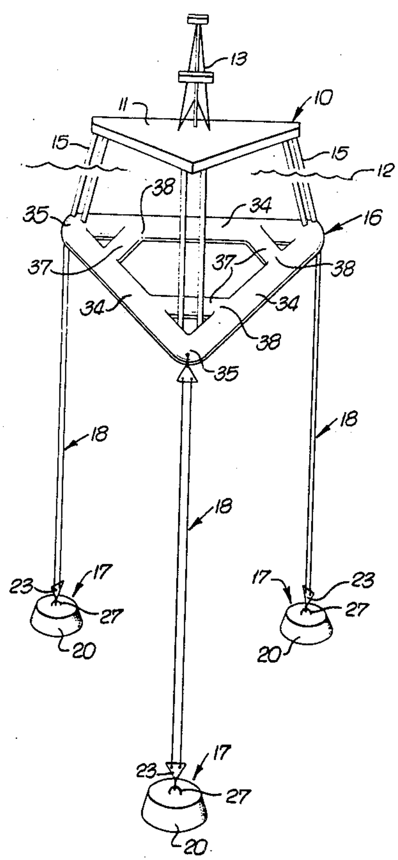

FIG. 1.

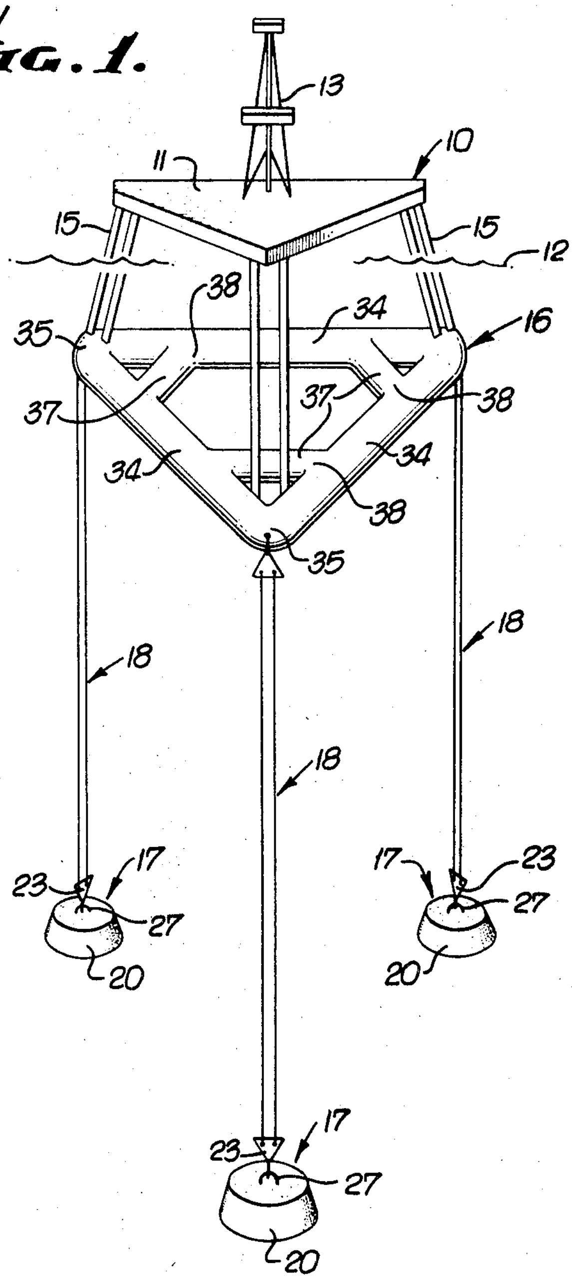

FIG. 2.

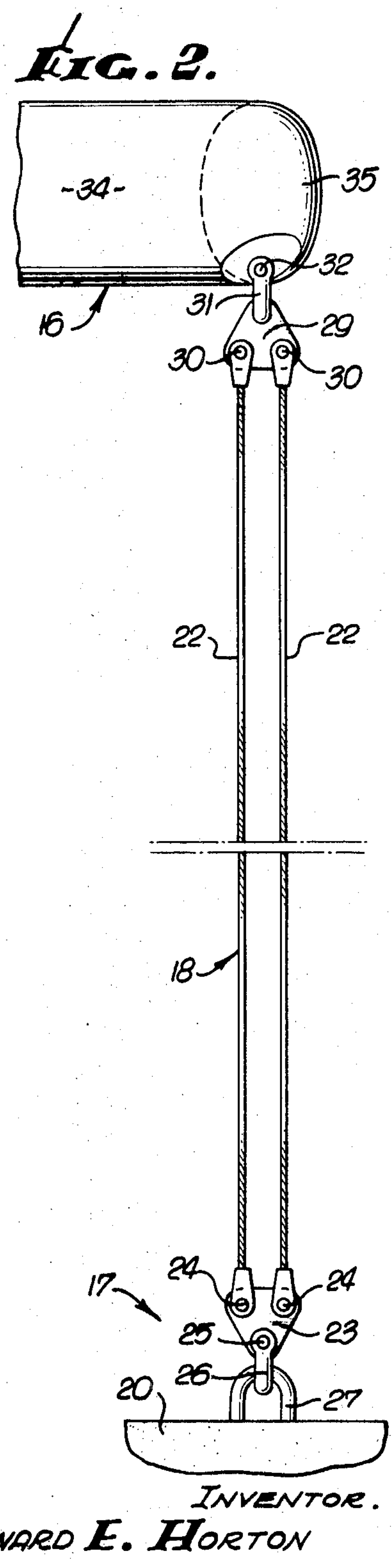

FIG. 3.

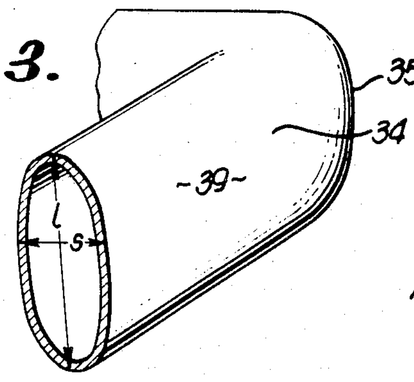

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FIG. 4.

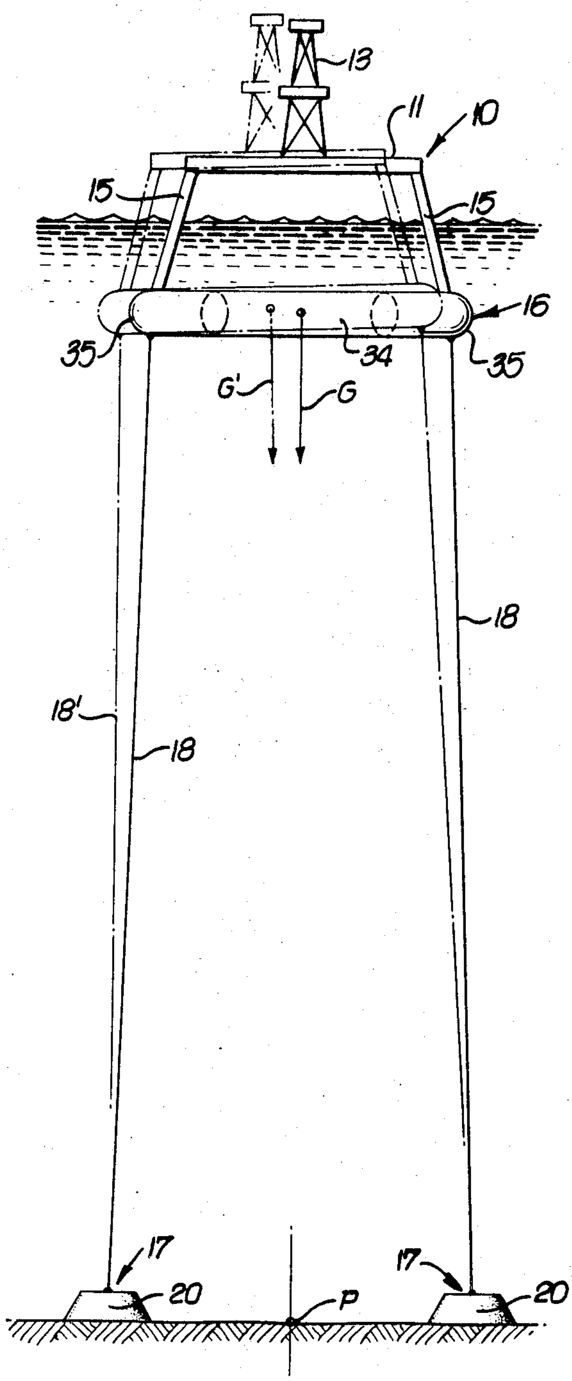
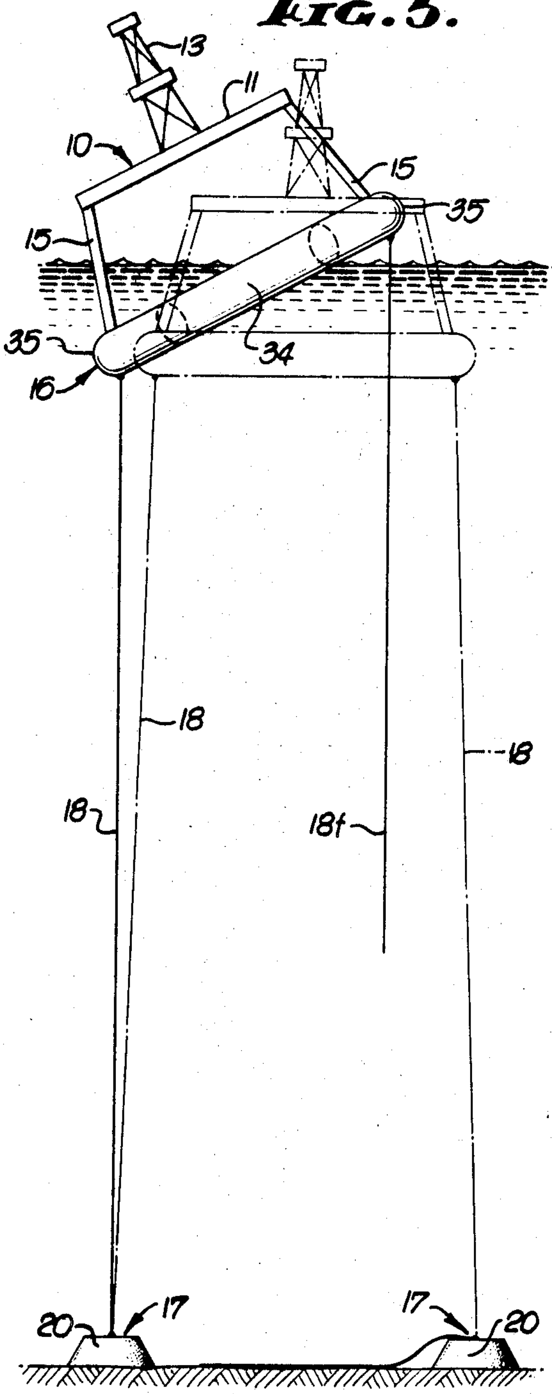


FIG. 5.



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STABLE MARINE CONSTRUCTION

BACKGROUND OF INVENTION

Offshore drilling platforms for conducting drilling and production operations over a wellhole have included various platform designs. In one of such prior proposed constructions tension means extending between anchor means at the sea bottom and submerged pontoon structure were maintained under tension and were generally either vertically disposed and parallel (U.S. Pat. No. 3,154,039) or extended outwardly from the pontoon structure in a relatively long sweep to provide mooring or anchoring of the platform at a distance therefrom while limiting relative movement thereof (U.S. Pat. No. 3,082,608). Most of the prior proposed offshore platform constructions were of indeterminate structure, that is of such configuration that the stress in the structural members were dependent on the deflections of the members. Further, the designs were such that a failure of one tension member would produce structural instability of the entire structure which would result in partial or complete failure of the offshore platform apparatus.

The installation of an offshore marine construction for well operations requires consideration of numerous factors, such as the depth of the water, wind conditions, ocean current conditions, severity of storms, various types of wave action, direction and force, and other natural conditions. In relatively shallow water, rigid platform legs could be extended to the ocean bottom and supported and anchored thereon. In deeper water, flexible tension lines were provided and the above water platform was supported upon a submersible buoyant means such as described in my copending application, Ser. No. 735,320. Such prior proposed submersible buoyant means varied in structure and included horizontally disposed parallel spaced cylindrical tubes, interconnected horizontally disposed cylindrical tubes, hollow column structure disposed with axes vertical, and generally large diameter hollow cylindrical bodies with axes vertically disposed. Such prior buoyant means were usually positioned sufficiently below wave action so that the effect thereof on the entire structure would be reduced to a minimum or eliminated. Where such structures were positioned at a depth in the zone of wave action, such prior proposed buoyant means were subjected to stresses which were caused by the action of the water particles and which produced longitudinal cyclic stresses on the tension member. In the event an anchor line failed, such prior structures became very unstable and sometimes capsized.

The present invention contemplates a marine construction which is stable and which reduces and minimizes the cyclic stresses imparted to the tension members and buoyant means by wave action, and which discloses a novel buoyant member useful in floating and submerged installations.

The primary object of the present invention, therefore, is to disclose and provide a marine construction for well operations which provides an optimum construction and installation for an offshore platform, particularly of the type anchored and supported by buoyant means and tension leg means.

An object of the present invention is to disclose and provide a marine construction which is stable under varying conditions and which under contemplated conditions is noncapsizable upon failure of one of the tension legs.

Another object of the invention is to disclose and provide a submersible buoyant means of novel construction which minimizes and reduces cyclic stresses imparted to the buoyant means and associated tension means by action of ocean waves.

A further object of the present invention is to disclose and provide a marine construction wherein a submersible buoyant means supports a platform above the water surface and wherein the buoyant means is provided with a novel configuration for reducing to a minimum cyclic stresses and for providing a determinate structure.

A specific object of the invention is to disclose and provide a buoyant member or pontoon of novel structure.

Various other objects and advantages of the present invention will be readily apparent from the following description of the drawings.

IN THE DRAWINGS

FIG. 1 is a perspective view of a marine construction embodying the present invention.

FIG. 2 is an enlarged fragmentary elevational view of one of the tension leg means shown in FIG. 1.

FIG. 3 is a fragmentary perspective view of a buoyant member embodying this invention, one end thereof being cut to illustrate the cross-sectional shape thereof.

FIG. 4 is an elevational view of a marine construction embodying the present invention illustrating shifting of the structure due to one of several conditions.

FIG. 5 is an elevational view similar to FIG. 4 illustrating the action of the marine construction in the event one of the tension leg means fails.

In the drawings a marine construction embodying the present invention is indicated at **10**. Generally speaking, such a construction **10** includes a working platform **11** supported at a suitable height above an ocean surface **12**. The platform **11** may support various and sundry well equipment for drilling and other well operations, drilling rig **13** being exemplary and schematically illustrated. Such well equipment may vary and loads carried by the platform may continually change within preselected limits with respect to the amount of load and location on the platform.

The exemplary marine construction **10** may also comprise a plurality of platform support columns **15** which may be structurally rigid and of selected length so as to support platform **11** at a selected height above surface **12** with supporting buoyant means **16** submerged at a preselected depth below surface **12**. Generally speaking, buoyant means **16** is maintained at a selected site in the ocean by a plurality of anchor means **17** and tension means **18** extending between and connecting the buoyant means **16** and anchor means **17**.

In detail, anchor means **17** may comprise a plurality of anchor members **20** of suitable weight and construction for firm anchorage in or on the ocean bottom. In this example, anchor members **20** may include a large heavy mass of dense material such as concrete. Other suitable anchor constructions may be employed. Anchor means **20** are arranged in a selected pattern and in this example may comprise anchor members **20** arranged at vertices of an equilateral triangle, the distance between two anchor members **20** being a predetermined distance related to the construction of the buoyant means as later described.

Tension means **18** may comprise suitable tension cables **22**, in this example, arranged in pairs, each pair being pivotally connected at their bottom ends as at **24** to a load equalizer plate **23** of generally triangular shape. Plate **23** may be pivotally connected at **25** to a U-shaped shackle member **26** which is interconnected with an eye **27** embedded and held in anchor member **20**. The upper ends of each pair of tension cables **22** are similarly pivotally connected to a load equalizer plate **29** at **30**, plate **29** having a pivotal connection to a shackle member **31** pivotally secured at **32** to a vertex portion of buoyant means **16**.

Submergible buoyant means **16** may comprise a plurality of peripherally continuous main buoyant members or pontoons **34** of oval or elliptical cross-sectional shape, as later described, and having an external equilateral triangular configuration generally corresponding to and aligned with and above the equilateral triangular spacing of the anchor members **20**. Each buoyant member **34** may be of the same length and is smoothly joined at its ends with adjacent ends of adjacent buoyant members **34**. Each vertex portion **35** provided by such joining of adjacent ends of buoyant members **34** is of a cross section corresponding to an oval or elliptical cross-sectional configuration of the main buoyant members **34** so that structural integrity and fluid dynamic characteristics of the buoyant means is substantially maintained through vertex portion 35 to provide a continuous peripheral buoyant construction of generally uniform similar cross-sectional shape. At each vertex portion the upper end of a tension means 18 is pivotally connected as previously described at 32.

Buoyant means 16 also includes intermediate or internal buoyant members 37 which extend between and are connected to adjacent main buoyant members 34 at a selected distance from the vertex portion of said members. Each internal buoyant member 37 is preferably of the same oval cross-sectional configuration as that described for main buoyant members 34. In the present example, internal buoyant members 37 may be connected at 38 to main buoyant members 34 at locations approximately one-third of the length of the main buoyant member and are parallel to the opposite member 34. The internal buoyant members 37 and center portions of external buoyant members 34 between connections 38 form a hexagonal structure which is symmetrical with respect to the center axis of the buoyant means. The internal buoyant members may be joined with the external buoyant members by suitable welding so that the cross-sectional configuration of the internal and external buoyant members is generally maintained.

Means for imparting stability to the marine structure 10 includes the particular construction of buoyant means 16 and the manner in which it is moored or held by tension means 18. With respect to buoyant means 16 it is important to note that the normal undisturbed position of buoyant means 16 with respect to the anchors 20 is such that tension means 18 are not vertical nor lie in parallel relationship, but instead are provided a relatively small amount of scope or inclination from the vertical in the order generally of one horizontal unit to 10 or 20 vertical units. Thus, depending upon the ocean depth at the selected location, the placement of the anchor means will provide a triangular area of greater area than the triangular area of buoyant means 16 as measured between the pivotal connections of the tension means 18. Such downward and outward flaring of tension means 18 provides limited lateral movement of the submerged buoyant means 16 with respect to the vertical axis of the buoyant means and anchor pattern without causing excessive displacement from horizontal of the buoyant means and associated platform.

In addition, such scope in tension means 18 provides means for laterally shifting the position of the platform with respect to a wellhead or equipment located within the anchor pattern. For example, without shifting the center of gravity G, and since there are three tension means, each at a vertex portion of buoyant means 16, increasing tension in one of said tension means will tend to move or displace the platform in a direction toward the corner of the triangular arrangement where the said one tension means is imparted increased tension as by suitable chain jack means, winch lines, or other well-known tension devices.

In the exemplary construction described above wherein the tension means are slightly inclined or provide a small amount of scope, lateral repositioning of the platform may also be accomplished by shifting the center of gravity or center of mass of the marine structure as by shifting ballast in the pontoons, equipment or weights on the deck or by other means (FIG. 4). In normal desired position the center of gravity G of platform 11 may be vertically aligned with a center point P of the triangular anchor pattern, and tension forces in each of the tension means 18 are virtually equal. When the center of gravity G is shifted to G′ which may be at a location not directly above P, it will be apparent that tension in the mooring line 18′ will become less and the buoyant means and platform will shift toward line 18′. Such change in tension may also be accomplished by changing the location of the center of buoyancy, in this instance by shifting the center of buoyancy to the right. Thus, when the center of gravity or center of buoyancy are laterally shifted, it will be apparent that the inclination or scope of tension means 18 will readily accommodate such shift in center of gravity and the platform may be repositioned laterally as desired within the limits of such scope.

Means for enhancing stability of the platform through the novel arrangement of buoyant means 16 and anchor means 18 also includes the shape and construction of means 16, particularly buoyant members 34 and 37. Factors which influence the action of buoyant means 16 and the platform thereabove include action of the ocean against the submersed buoyant means 16 when it is located in the zone of wave action and held by tension means 18 as above described. Movement of a submerged wave against buoyant means 16 includes consideration of the amplitude of the wave, the wave period, drag and inertia forces acting upon the buoyant means, and the elasticity of the tension means 18 which anchor the submerged buoyant means in a selected position. The oval cross-sectional configurations formed by the external surfaces 39 of the walls of members 34 and 37 are important with respect to the type of motion imparted to buoyant means 16 by waves or wave particles acting thereagainst. As exemplarily shown in FIG. 3 configurations embodying this structure are oval, elliptical, or a variation thereof wherein a cross section of each buoyant member includes a major or long axis disposed vertically and a minor or short axis disposed horizontally. Forces developing from changes in velocity of water particles as they are influenced by the presence of the submerged buoyant means 16 may be considered as a function of the relative velocity between the body and the water and also as a function of the acceleration of a water particle relative to the body. The function with respect to velocity may be mathematically expressed as:

$$F_D = V^2 C_d A \rho$$

where F_D = the force developed by drag
V = relative velocity of water and object
C_d = drag coefficient which is a characteristic of the shape of the object
ρ = mass density of the water.

The function of the acceleration of the water particle relative to the submerged body may be expressed by the following formula:

$$Fi = CiD$$

where Fi = the force developed by the inertia of the water particle
Ci = inertia coefficient
a = acceleration of water particles
D = displacement of the object
ρ = the mass density of the water

The above functional expressions illustrate that both drag and inertia coefficients are dependent upon the shape of the submerged body and particularly the shape of the external surface in contact with the water particles. It has been found that when a submersible buoyant member has a generally oval cross-sectional configuration where the relationship between a vertically disposed major axis and a minor axis is two to one, the value of the inertia coefficient Ci may equal approximately 1.5 in the vertical direction. The value of the drag coefficient Cd is substantially reduced for the oval shape, the amount being a function of the Reynolds number relating to the system. Drag coefficient may be reduced by about 50 percent by using an oval or elliptical shape for buoyant members 34, 37.

When submerged buoyant means 16 includes buoyant members having the same displacement per foot of length and a major-minor axis ration of 2:1, cyclic forces in a vertical direction developed by wave passing the submerged body may be expressed by the following formulations where K is a unit of force:

$Fi\,(\text{ellipse}) = 0.75\,\pi K$,
$Fi\,(\text{ellipse}) \geqq 0.5\,K$.

When the ratio of the major axis to the minor axis of the oval shape increases, the inertia force for a given displacement in the vertical direction will decrease. Under such conditions horizontal or laterally acting forces imparted to buoyant members 34, 37 will increase and will tend to move the platform away from its normal location. Thus, when the type of wave action expected at a particular location is determined, the oval cross-sectional shape of the buoyant member may be selected so as to provide an optimum shape under such expected ocean conditions.

In general, an oval cross-sectional configuration of a submersible buoyant member made in accordance with the present invention will include a vertical major axis in the order of from 1.2 to 2.5 that of the horizontal or lateral axis. In this respect while the example of FIG. 3 shows a geometric oval configuration, the invention contemplates modifications of the oval shape depending upon the particular ocean conditions prevalent at a selected offshore site. A desired relationship between the major and minor axes may be satisfied, for example, by two half-circles jointed to opposite ends of a rectangle.

The cross-sectional configuration of the buoyant member has been described in connection with the entire structure of buoyant means **16**. It will be understood, of course, that the invention contemplates a buoyant member of oval or elliptical cross-sectional configuration which may be used in other types of submerged construction and that it is not necessarily limited to use in a triangular arrangement of buoyant members which is part of the present invention. The relationship between major and minor axes of a cross-sectional configured submerged body and its reaction to ocean movement provides a construction wherein drag forces are substantially and effectively reduced and wherein, because of the relationship of such axes, inertia forces acting in a vertical direction are substantially reduced. Thus, the invention contemplates a submerged body construction of the type as described above for buoyant member **36, 37** as providing unique marine characteristics which may be desirable in other installations wherein such a buoyant body is required to support another structure and aid in maintaining effective stability.

It should be further noted that submerged buoyant means **16** of the above-described construction also provides stability to the marine structure in the event a tension means or a mooring line should fail. Such failure condition is shown in FIG. **5** where a tension means **18** has become disengaged with its anchor means **20** as by failure and breaking of the mooring line along its length as at **18***f*, or in some way has become disconnected with buoyant means **16**. When such a failure occurs, it will be apparent that the vertex portion **35** of buoyant means **16** at which the failed tension means is connected will rise in the water while the opposite buoyant member **34** will rise above its normal depth and will be held by the other two tension means **18**. When buoyant means **16** is installed at a preselected depth contemplated for the structure of this invention, the intermediate buoyant member **37** will rise to the surface of the water and may ride on the surface thereof. When intermediate buoyant member **37** rides on the surface of the water, the tipping or overturning forces acting on the marine structure are substantially reduced and such condition tends to sufficiently stabilize the structure to prevent capsizing or overturning in the water. In addition, it should be noted when tension line **18** fails, the points of connection of the other two tension lines **18** to respective vertex portions **37** opposite the failed line move closer to the sea surface because of the amount of scope provided for the tension lines.

In the above description of the present invention it will be understood that the method of installing a marine structure at a selected site may be accomplished by the system described in my copending patent application Ser. No. 735,320, or any other method for submerging the buoyant means **16** to a selected depth may be employed. Marine structure **10** is generally illustrated and details of construction of the platform, supporting platform legs, tension means, and ballast means for buoyant means **16** which might be employed in installation of such a construction have not been described.

The marine structure **10** embodying the invention described above thus provides a platform of determinate structure which is stable when the buoyant means **16** is submerged and held at a selected site by either one, two, or three tension means as well as when the buoyant means is located on the surface. Moreover, the buoyant means is particularly constructed so that the buoyant members are of generally oval shape with the major axis of the buoyant members vertical and at least from 1.2 to **2.5** times the minor axis in order to reduce and minimize drag and inertia forces imposed upon the structure by wave action. The general equilateral triangular configuration of the anchor pattern and corresponding triangular configuration of the buoyant means with interconnecting tension means provided with a selected scope or inclination together with the provision of intermediate symmetrically arranged buoyant members provides a marine structure having a high degree of stability and resistance to overturning when one of the tension members fails. The marine structure **10** may move laterally from wave, current, and wind forces within acceptable limits without becoming unstable.

It will be understood that various modifications and changes may be made in the marine structure described above and which come within the spirit of this invention and all such changes and modifications coming within the scope of the appended claims are embraced thereby.

I claim:

1. In a normally submerged marine construction adapted to support a platform above water surface and adapted to minimize cyclic stresses caused by ocean conditions, comprising in combination:

- a plurality of anchor members positioned in a selected pattern at sea bottom;
- buoyant means including a plurality of peripherally continuous main buoyant members located above said anchor members and having an external configuration generally corresponding to and in alignment with the selected anchor pattern;
- a plurality of negatively buoyant tension means each interconnecting one of said anchor members with a juxtaposed part of one of said buoyant members and forming with said buoyant means a determinate structure; and
- internal buoyant members arranged about the center of said buoyant means and diagonally interconnecting adjacent portions of contiguous main buoyant members for enhancing stability of said marine construction.

2. In a marine construction as stated in claim **1** wherein said anchor pattern is slightly larger than the configuration of said buoyant means whereby said tension members are inclined and nonparallel.

3. A marine construction as stated in claim **1** wherein said internal buoyant members are spaced a distance from the connection of the opposed tension means to the buoyant means and said buoyant means are spaced below the ocean surface such that an internal buoyant member will be positioned on the surface of the ocean upon failure of an adjacent tension means.

4. A marine construction as stated in claim **1** wherein each of the external and internal buoyant members is horizontally positioned and is of oval cross section with its major axis vertical.

5. In a marine construction as stated in claim **1** wherein said internal buoyant members are connected to said external buoyant members at locations approximately one-third the length of the external buoyant member.

6. In an offshore marine construction adapted to be submerged and to support a platform means above the sea surface, the combination of:

- a plurality of anchor means arranged in a triangular pattern;
- buoyant members arranged in a corresponding triangular pattern of less area with vertices of the buoyant triangular pattern generally opposite said anchor means;
- tension means interconnecting said anchor means and vertices of said buoyant means, said tension means being inclined downwardly and outwardly; and
- buoyant members interconnecting said first-mentioned buoyant members at locations spaced from said vertices.

7. A submersible buoyant system for use in offshore well operations comprising:

an elongated hollow body buoyant member in submerged position exerting an upwardly directed force and having a longitudinal axis horizontally disposed and provided with an external surface of uniform cross-sectional oval shape throughout its length;

said oval cross-sectional shape including a major axis normally disposed in a vertical direction;

said major axis varying from about 1.2 to 2.5 times the length of the minor axis;

and tension means connected to said buoyant body member restraining said upwardly directed force thereof,

whereby vertical components of forces of wave action are virtually cancelled and other force components of wave action relating to drag and inertia are minimized.

8. In a marine construction as stated in claim **4** wherein the major axis of the oval cross section of said buoyant members is at least from 1.2 to 2.5 times the length of the minor axis.

9. An offshore marine construction as stated in claim **6** wherein each buoyant member is provided with an external surface configuration providing a generally oval cross section having a major axis of said oval cross section vertically disposed.

10. A submersible structural system for an offshore platform construction; comprising:

an elongated hollow buoyant body member adapted to be horizontally submerged to depths in the vicinity of subsurface wave action;

tension means connected to said body member for retaining said body member at a selected depth,

and means for reducing drag and inertia forces imposed on said body member by such wave action and comprising

an external surface configuration on said body member responsive to said wave action to stabilize said body member,

said surface configuration forming in transverse cross section a uniform generally oval shape with the long axis of the oval shape disposed vertically and having a length in the order of 1.2 to 2.5 times the short axis of the oval shape.

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,577,946 Dated May 11, 1971

Inventor EDWARD E. HORTON

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

Column 4, line 38, delete [Fi=CiD] and insert --Fi=Ci aD--.

Column 5, line 12, delete [jointed] and insert --joined--.

Signed and sealed this 14th day of March 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents