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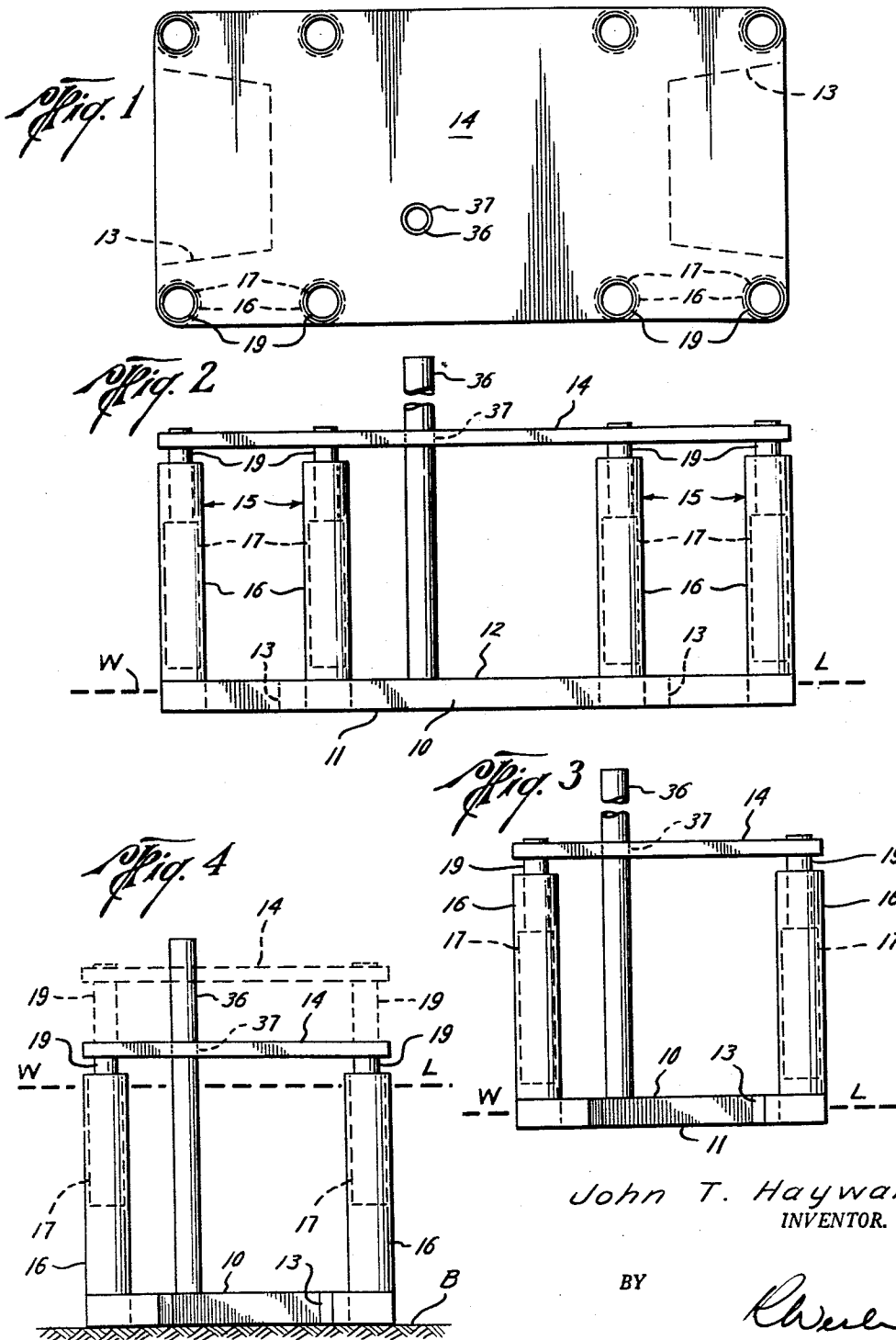
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2,960,833

MARINE FOUNDATION STRUCTURE

Filed Nov. 10, 1955

2 Sheets-Sheet 1



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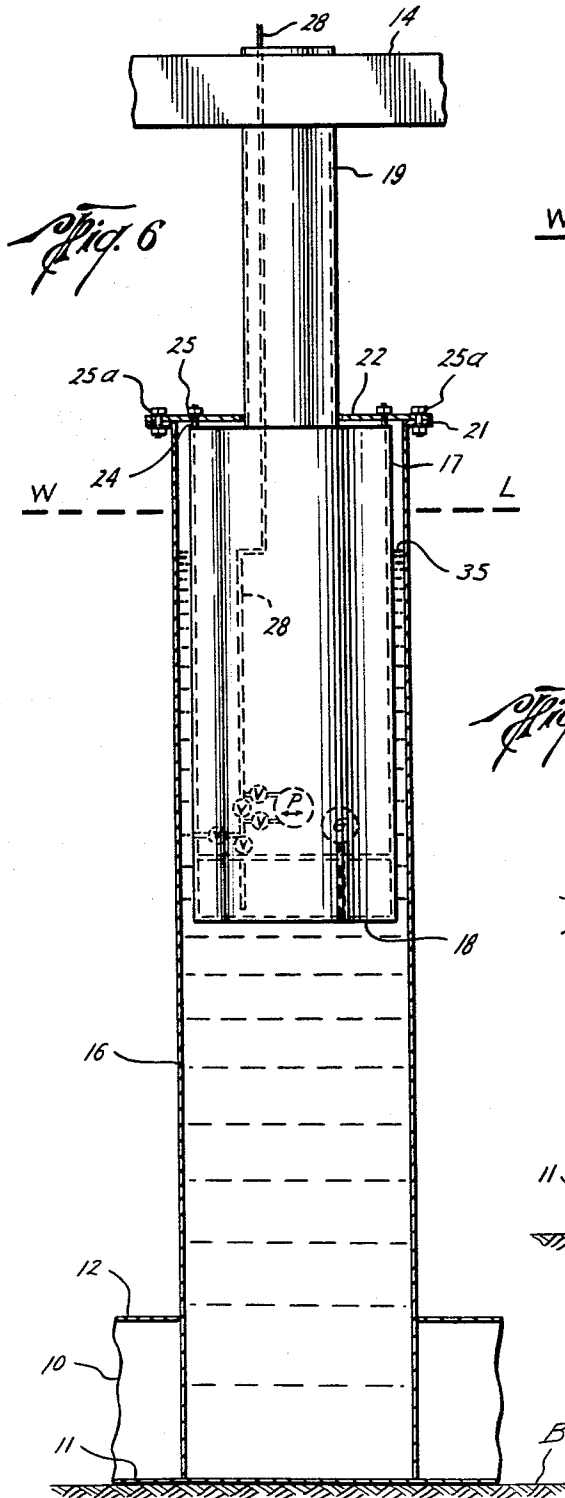
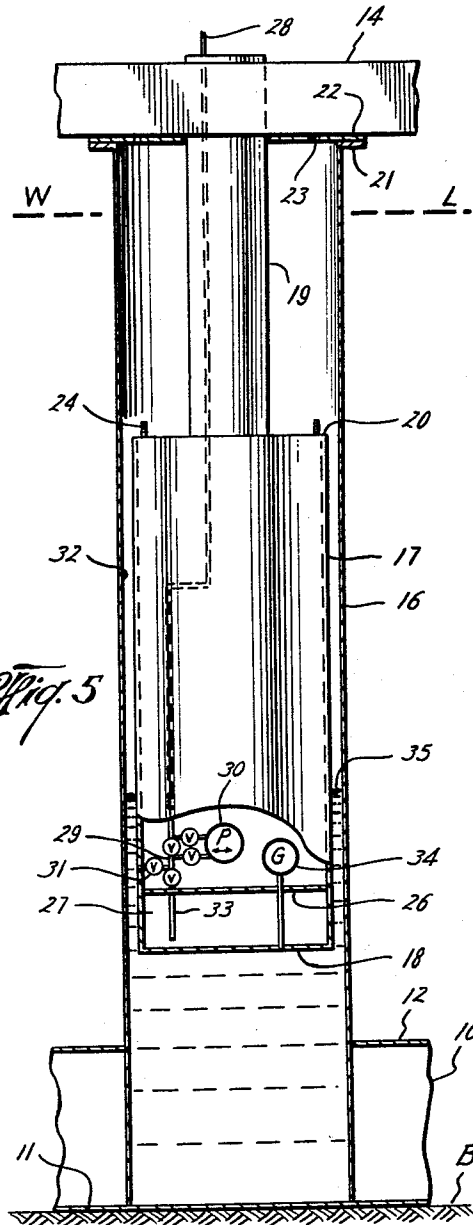
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MARINE FOUNDATION STRUCTURE

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2 Sheets-Sheet 2



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2,960,833

MARINE FOUNDATION STRUCTURE

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15 Claims. (Cl. 61—46.5)

This invention relates to a portable marine foundation for supporting drilling rigs employed for drilling wells in water locations and particularly to a submergible hull type foundation.

Various types of foundations have been developed for use in drilling oil and gas wells in water locations, particularly in the submerged lands lying off shore in the Gulf of Mexico. Among the more successful types of such foundations have been the portable, submergible types disclosed in my U.S. Patents Nos. 2,540,878, 2,551,375, 2,612,759 and 2,699,042. These, generally speaking comprise a floatable-submergible base hull to which is secured a plurality of upwardly projecting columns which are secured to and support a working platform or deck in elevated relation to the base hull. The vertical distance between the hull bottom or keel and the underside of the working platform or working deck (this distance being referred among workers in the art as "KD") is generally selected with relation to the water depth in which the structure is to be used, so that when the hull is submerged and on-bottom, the underside of the working deck will be about 30 feet above the mean water level so as to clear the highest waves which may be anticipated in the locations where the structure is to be used.

This type of barge, with a working platform at a fixed elevation with respect to the hull, has proven very successful in drilling in comparatively shallow water depths, for example, from about 20 feet to about 50 feet. It will be obvious, however, that such structures, when designed for use in water depths of 80 to 100 feet or more, will, when afloat, necessarily extend to such great heights above the water as to become difficult to tow or navigate and generally hazardous to move from one location to another on the water surface.

Various modifications of the basic design of such structures have been made in an effort to overcome the difficulties occasioned by the excessive height and cumbersome construction when designed for use in relatively deep water. In one arrangement a double hull is employed, the two parts being superimposed and connected together by columns sliding vertically through the upper hull. In this instance, the lower hull is submerged while the upper hull remains afloat and thereafter the upper hull is raised up on the connecting columns by some type of jack means until it is elevated at a satisfactory height above the mean water level. In another, a plurality of hull sections is employed, also using columns slidably connecting the working platform to both the hulls. The arrangement is such that the platform is supported on one portion of the hull at the desired height above the water, this hull portion being maintained in floating condition, while the other portion of the hull is submerged and seated on the underlying land. Thereafter, the platform is secured to the columns carried by the submerged hull portion, while the other or floating hull portion is either removed or also sunk to the bottom

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and has its columns then secured to the working platform.

Other modifications of these arrangements have been employed, but all present various structural and operating problems and are relatively expensive and complicated to construct.

The present invention has for its principal object the provision of a foundation construction which will be substantially lower in overall height when afloat than more conventional constructions designed for use in corresponding water depths.

A further object is to provide a marine foundation including a submergible hull and a working platform, the working platform being supported on a plurality of floats each of which is buoyantly disposed in a separate and non-interconnected body of liquid carried on the submergible hull.

An additional object is to provide a marine foundation including a submergible hull and a working platform, the hull carrying a plurality of vertically extending columns containing separate, non-interconnected bodies of liquid and the working platform being supported by a plurality of float members extending into the columns and supported on the water bodies contained therein, the elevation of the platform relative to the hull being variable by varying the extent of the submergence of the float members in the separate water bodies contained within the columns.

Still another object is to provide a marine foundation including a submergible hull having a plurality of relatively large diameter hollow columns mounted thereon to extend a short distance above the mean level of a water body in which the hull is to be submerged, and a working platform supported on a plurality of hollow tubular float members extending into the columns carried by the hull, the elevation of the working platform relative to the hull being adjustable by varying the depth of separate bodies of liquid contained in the several columns whereby to vary the submergence to displacement of the float members therein.

Still another object is to provide a marine foundation including a submergible hull having a plurality of relatively large diameter hollow columns mounted thereon to extend a short distance above the sea level in which the hull is to be submerged, and a working platform supported on a plurality of hollow tubular float members extending into the columns carried by the hull, the elevation of the working platform relative to the hull being adjustable by ballasting the float members whereby to vary their submergence and displacement in the separate bodies of liquid contained in the several encircling columns.

In accordance with the present invention, the submergible hull is provided with a plurality of upwardly extending relatively large diameter hollow columns having a length such as to extend only a short distance above the mean water level in the area of operation when the hull is seated on the underlying land. The working platform is provided with a corresponding number of downwardly projecting hollow columns of smaller diameter than the hull columns, so that a substantial amount of clearance is provided between the inner and outer columns when they are telescopically interengaged. The deck columns are closed at their lower ends forming hollow floats.

The hull columns are adapted to form receptacles or containers for separate, hydraulically non-communicating bodies of liquid, such as sea water, in which the respective deck floats are separately immersed. Means is provided for varying the depth of the liquid bodies in the several columns to thereby vary the extent of submergence of the deck floats therein whereby to correspondingly

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vary the displacement of the deck floats in the respective water bodies. By thus increasing the extent of submergence of the floats to a point at which their displacement will exceed the loads supported thereby, the floats will be caused to rise inside the outer columns and thereby raise the working platform. Similarly, by lowering the fluid levels in the outer columns the floats will be caused to sink and thereby lower the deck.

Other and more specific objects of this invention will become more fully apparent from the following detailed description when read in conjunction with the accompanying drawing which illustrates a useful embodiment in accordance with this invention.

In the drawings:

Fig. 1 is a plan view looking downwardly on the working deck of a foundation structure constructed in accordance with one embodiment of the present invention;

Fig. 2 is a side elevation of the foundation structure showing the structure in floating position on a water body;

Fig. 3 is an end elevation of the structure in floating position;

Fig. 4 is an end elevation similar to Fig. 3, showing the hull in the fully submerged position, the working platform being shown in its non-elevated position in solid lines and in its elevated position in broken lines;

Fig. 5 is an enlarged longitudinal sectional view of one of the telescoping column units connecting the hull and the working platform, the parts being generally in the retracted position illustrated more schematically in Fig. 3; and

Fig. 6 is a view similar to Fig. 5, showing the column unit of Fig. 5 in the extended or deck-elevating position.

Referring to the drawing, the structure comprises a hull 10 of generally rectangular hollow box-like construction having a substantially flat bottom 11 and a deck 12. The opposite ends of hull 10 may be provided with bays 13—13 through which drilling operations may be conducted. It will be understood that hull 10 will be suitably compartmented and provided with appropriate ballast transferring equipment conventionally required for effecting submergence and refloating of the hull. A working platform 14 of any suitable and generally conventional design is supported on hull 10 by means of a plurality of longitudinally and laterally spaced telescoping column units, each designated generally by the numeral 15. The column units 15 are of identical construction and one of these units will be described in detail, it being understood that all of the other column units of the illustrative embodiment are of substantially identical construction and operate in the same manner.

The column unit 15 comprises an outer hollow column 16 which is connected to hull 10 and projects upwardly therefrom to a height such that its upper end will be only a short distance above the mean water level of the water body in which the structure is designed to operate, the upper end of the outer column 16 being open. The other element of the column unit comprises a hollow inner column 17 closed at its lower end by an end wall 18. Column 17, herein sometimes referred to as the float column or float, may have its diameter reduced substantially at an intermediate point thereof to form thereabove the reduced diameter portion 19 and thereby defining the annular upwardly facing shoulder 20 at the juncture of the two portions of the inner column. The upper end portion of column portion 19 is suitably secured to deck 14. The upper end of outer column 16 may be provided with an annular flange 21 and an annular bolt flange 22 slidably surrounds portion 19 of the inner columns so as to float thereon and is adapted to rest on flange 21. Bolt flange 22 is provided with a plurality of circumferentially spaced openings 23 adapted to receive a plurality of upstanding studs 24 secured to shoulder 20, whereby the inner column or float may be secured to the bolt flange by means of the nuts 25 (Fig. 6) for purposes

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to be described hereinafter. Securing means, such as bolt means 25a may also be provided for securing bolt flange 22 to flange 21 for purposes to be subsequently described. Inner column 17 may be provided with an internal bulkhead 26 spaced above end wall 18 to define a ballast chamber 27 in the lower end of the float column for purposes to be described more fully hereinafter. A pipe 28 extends from above deck 14 interiorly of the inner column and connects, by means of a suitable valved manifold 29, to a pump 30. Manifold 29 is provided with a valved branch connection 31 communicating with the annular space 32 between the inner and outer column members. Another valved manifold branch 33 communicates with the interior of chamber 27. By means of the pump 30 and the manifold arrangement, liquid, usually sea water, designated by the numeral 35, may be pumped into or withdrawn from outer column 16 and annular space 32 or into or from ballast chamber 27, as may be required in the course of operations to be described hereinafter. A differential pressure gage 34 of any conventional construction may be connected through end wall 18 to provide an indication of the load on each of the inner columns.

A continuous tubular column 36, generally of smaller diameter than the elements of column unit 15, communicates through hull deck 12 with the interior of the hull and extends upwardly through an opening 37 in deck 14 so that the deck will slide freely over column 36. The overall length of the latter will be made such that its upper end will extend somewhat above deck 14 when the latter is in its maximum elevated position. Column 36 is designed to serve as an access trunk for utility lines and for personnel passing between the deck and the interior of the hull which may house machinery and materials employed in the operation of the structure. Access to the interior of column 36 may be through its upper end or through doorways (not shown) which may be provided in the wall thereof at various levels corresponding to the raised and lowered positions of the deck. It will be understood that the structure may include more than one of the columns 36 for providing additional communicating trunks to the hull.

When afloat and moving over the water surface deck 14 will be in the lowered position with floats 17 fully retracted within outer columns 16, as best seen in Figs. 2 and 3. When the location is reached at which operations are conducted hull 10 will be submerged to sink it to rest on land bottom B. The manner in which the hull is submerged may be in accordance with any generally conventional procedure well known to those skilled in this art. My aforementioned Patent No. 2,551,375 describes one highly effective and safe procedure for this purpose. Fig. 4, in full lines, illustrates the positions of the structure and the main elements thereof when hull 10 is submerged to rest on land B. Deck 14 is now raised to the desired elevated position indicated by the broken lines in Fig. 4 by the above described means and in the manner to be subsequently described. Briefly stated, the operation of raising deck 14 is accomplished by increasing the depth of liquid 35 in the interior of columns 16. Similarly, once raised, the deck may be lowered by reducing the depth of liquid 35 in the interior of columns 16.

The mode of operation and the novel features of this invention may be best described by employment of a specific example, it being understood that the dimensions given and the other figures are exemplary only and are in no way to be deemed limitative of this invention.

It will be assumed that the structure is designed for operation in water having an average depth of about 80 feet and that the working platform or deck 14 is to be elevated to a height such that its underside will be approximately 30 feet above the mean water level when in working position. A suitable size for such a structure would include a hull approximately 200 feet long by 120 feet wide, and having a molded depth of about 13 feet. Outer columns 16 will be made to have an inside diameter

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of approximately 18 feet. Float columns 17 will have an external diameter of about 16 feet, whereby annular space 32 will have a width of about 1 foot. It will be obvious that with this large amount of clearance between inner columns 17 and outer columns 16 that these cannot act as hydraulic rams and liquid introduced into the interior of outer columns 16 may rise freely into annular space 32 and fall freely as liquid is withdrawn from the interior of the outer columns. Upper portion 19 of the inner column member will preferably have a substantially reduced external diameter, say about 8 feet or less, in order to reduce the area exposed to wind and wave action when the deck is raised. It will be understood, however, that the inner column may be of uniform diameter throughout its length. The outer column 16, for the water depth mentioned, will preferably be about 85 feet in length, as measured from bottom 11 of hull 10 to the upper ends of the columns carrying flanges 21. Thus when the hull is on bottom B, the upper ends of outer columns 16 will extend about 5 feet above the mean water level WL of the water body in which the structure is positioned. The inner columns, measured from the underside of deck 14, are made substantially shorter than the outer columns, for example about 20 feet shorter, so that the lower ends of the inner columns will be spaced above the lower ends of the outer columns and when fully retracted into the outer columns, deck 14 will rest on flanges 21, bolt ring 22 being disposed between flanges 21 and the lower face of deck 14, as best seen in Fig. 5.

It will be further assumed, for purposes of the illustrative embodiment, that eight of the column units 15 will be employed, spaced in any suitable arrangement, and that the entire load supported by these columns, including deck 14 and all equipment and material carried thereon, will be approximately 1600 tons. It will be assumed that the load is uniformly distributed, although that is obviously not necessarily true in actual practice, and each column unit, therefore, will be required to support approximately 200 tons.

Fig. 5 shows one of the column units with the portions of the deck, hull and other parts of the structure in their relative positions after the foundation structure has arrived on location and has been sunk to bottom. The water level outside the column unit would be 80 feet, as previously stated, and at this time liquid 35, inside outer column 16, will be at some relatively low level, for example, 30 feet. With a 30 foot water level in column 16, about 10 feet of the lower end of float column 17 will be submerged. The latter being 16 feet in diameter, as noted, will have a displacement in sea water of 6.4 tons. With 10 feet submerged, therefore, there would be an upward force on inner column 17 of 64 tons. This, of course, is considerably less than would be necessary to give an upward force of 200 tons on inner column 17, which would be required to initiate lifting of the deck. 31 feet, 6 inches of a 16 foot diameter cylindrical column would need to be submerged in sea water to produce a displacement of 200 tons; hence, sea water will now be admitted to annular space 32 and when the level has risen therein until float column 17 has become submerged to a depth of 31 feet, 6 inches, the resulting upward thrust on column 17 will start it upwardly and will start raising deck 14. This raising movement will continue as the water level in annular spaces 32 of the several columns is raised. Finally, when the level of the underside of deck 14 has been raised to 25 feet above the top of the outer columns, it will then be 30 feet above mean water level, which is the elevation desired. The level of water in annular space 32 will now be eight or nine feet below the upper end of outer column 16. When the system reaches this position, inner and outer columns 17 and 16 are bolted together in the following manner: Shoulder 20 on inner column 17 will have risen to an elevation at which it will engage bolt ring 22 which will be resting on flange 21 and will lift it slightly off of flange 21. Studs 24 will be guided through openings 23 and secured to

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bolt ring 22 by means of the nuts 25. The water level in column 16 may now be lowered by pumping out a small amount of the liquid to allow the deck to descend sufficiently to impose a portion of the load on ring 22 and flanges 21. Bolt ring 22 may now be secured to flange 21, as by means of bolts 25a. The deck at all times will, therefore, be partially supported on the upper ends of columns 16 and partially by the water in the interior of columns 16 and in the annular spaces 32. Preferably the load thus imposed on the outer columns will be live load of the deck.

It is important to note that during the raising and lowering operation, deck 14 will be floating on columns 17 and does not depend for stability upon any guiding action between the telescoped parts of the inner and outer columns. If the entire deck and its float columns were lifted out of columns 16 and floated in the sea, it would be stable and in this example would have a metacentric height (GM) of some 10 to 20 feet. This would not be sufficient for adequate stability because owing to the relatively small displacement of the floats it would mean that a comparatively small increase in load on one side would cause that side to descend an appreciable distance. The structure of the present invention, however, greatly increases the stability of the structure for the following reasons: Instead of the deck portion floating in open water, it is floating in the outer columns which are not inter-connected at their lower ends; therefore, the bodies of water in each of the columns are confined therein, are entirely separate and are not in hydraulic communication with each other. In the present structure, if the load is increased on one side so as to tend to depress that side, the draft of the float columns on that side will be increased by an amount corresponding not only to the inclination of the deck, but also by an amount due to a rise in the water level in annular space 32. This latter effect is one which I have discovered and which results in the increased stability of the deck structure. The increase in stability or righting moment, due to the change of water level in the outer columns, multiplies the righting moment by a factor:

$$f = 1 + \frac{d^2}{D^2 - d^2}$$

where

d = outside diameter of inner column 17

D = inside diameter of outer column 16

Using the dimensions noted previously, namely, 16 feet diameter for inner column 17 and 18 feet internal diameter for outer column 16, factor f in the above formula will be about 4.7 and in a structure of the dimensions given in the present example will give a metacentric height (GM) of approximately 100 feet.

The increased stability thus provided by the structure in accordance with this invention permits the raising and lowering of the deck to and from the desired level by the very simple operation heretofore described of introducing and removing sea water from the interior of the outer column 16.

Moreover, it will be seen that during the raising and lowering operation, the working deck will be floating in completely calm and currentless waters subject only to the relatively moderate side pressures which might be exerted by normal wind velocities, since the raising and lowering operations will ordinarily be conducted during periods when normal weather conditions occur.

In the illustrative example, it will be seen that where design for use in water of 80 feet depth, the KD dimension of the structure would only be about 85 feet as contrasted with a fixed deck arrangement for the same water depth which would require that the KD dimension be at least 110 feet.

The equipment necessary to raise and lower the deck is quite simple and flooding and de-flooding of the outer

columns may be done either through the hull, or through each individual column by the piping arrangement illustrated and described heretofore.

While it is ordinarily desirable, so far as possible, to keep the levels of liquid in the annular spaces 32 of all of the column units the same height during raising and lowering, this is not essential for if the load on deck 14 is not symmetrically distributed, more up-thrust would be required from one float than the other. With the level of water in all the annular spaces equal, this variable up-thrust could be obtained by ballasting the lower ends of inner columns 17. It is for this purpose that bulkheads 26 and ballast chambers 27 are provided in the inner columns. Ballast can be introduced into and removed from chambers 27 by means of pump 30, manifold 29, and branch pipe 33. By this means, the upthrust of each of the float columns may be controlled independently of the fluid level in the respective annular spaces 32.

Still another modification of the method of raising the working deck comprises the following procedure: With the hull on bottom and the deck in lowered position as indicated in Figs. 4 and 5, water is admitted by any suitable means to the interiors of both the inner and outer columns to equalize the levels therein with the depth of the surrounding water body which, as in the previous example, will be taken to be 80 feet. Water will then be pumped out of the inner columns, while the outer columns are kept filled to the original level. Using the figures and dimensions of the previous example, namely, a load of 200 tons on each column and the displacement of the 16 foot inner column of 6.4 tons per foot of sea water, it will mean that when the water level in the inner columns has been lowered about 31 feet, 6 inches below that in the outer columns, the deck will start to lift. Pumping out of the inner columns is then continued until the deck has risen to the desired height. The deck may be lowered either by refilling the inner columns, by lowering the level in the outer columns, or by a suitable combination of both operations.

As the loading on each column determines the depth of liquid to be maintained in the annular space, or the amount of ballast to be maintained in inner columns 17, it is important to know the actual load on each column and suitable measurement means, such as differential pressure gage 34, is provided for this purpose.

It will be understood that, although for purposes of illustration the column units 15 have been described as being substantially identical in dimensions, in many instances it will be desirable to have the column units of different diameters to match the permanent loading on the working platform. Moreover, the number of column units and spacing and their relative locations may be varied for each individual case. At least three column units will be required in every case. Where three column units are employed it will be understood that they will preferably be arranged in a triangular pattern.

The relative diameters of the inner and outer columns may be varied widely. In general, the inner columns should have a diameter at least one-half the internal diameter of the outer columns and may range up to about 95% of the internal diameter of the outer columns. In every instance, as noted, the clearance between the inner and outer columns should be sufficient to provide not only free movement between the columns, but also sufficient space to allow the water level to rise and fall freely in the annular space between the columns during the raising and lowering of the deck.

Stated in terms of the formula set out above, d may range from about $0.5D$ to about $0.95D$. Factor f correspondingly will range from about 1.32 to about 9.3.

It will be understood that numerous alterations and modifications may be made in the details of the illustrative embodiments within the scope of the appended claims but without departing from the spirit of this invention.

What I claim and desire to secure by Letters Patent is:

1. A marine foundation structure, comprising, a hollow submergible hull member having ballasting means for submerging and refloating the same, a plurality of hollow columns mounted on the hull member to project above the surface of a water body when the hull member is submerged therein to rest on the underlying land, a body of liquid confined within each of said columns, a plurality of hollow float members extending into said columns and having their upper end portions projecting above said columns, a platform supported on said upper end portions, each of said float members being individually buoyantly supported by the body of liquid in the column in which it extends, and means for varying the liquid levels in said columns whereby to raise and lower the platform relative to the hull member.

2. A marine foundation structure according to claim 1 wherein said float members comprise hollow elongate column members closed at their lower ends, and having external diameters substantially smaller than the internal diameters of said columns to provide substantial annular clearance therebetween.

3. A marine foundation structure according to claim 2 wherein the diameters of said float members range from about 50% to 95% of the internal diameters of the outer column members.

4. A marine foundation structure, comprising, a hollow submergible hull member having ballasting means for submerging and refloating the same, a plurality of hollow columns mounted on the hull member to project above the surface of a water body when the hull member is submerged therein to rest on the underlying land, a body of liquid confined within each of said columns, a plurality of hollow float members extending into said columns and having their upper end portions projecting above said columns, a platform supported on said upper end portions, each of said float members being individually buoyantly supported by the body of liquid in the column into which it extends, means for varying the liquid levels in said columns whereby to raise and lower the float members relative to the columns to thereby raise and lower the platform relative to the hull member, and means for securing the float members to the columns when the float members are in raised position.

5. A marine foundation structure, comprising, a hollow submergible hull member having ballasting means for submerging and refloating the same, a working platform, and a plurality of laterally spaced telescopic column units connecting the hull member to the platform for adjustably elevating the platform relative to the hull member, each of said column units comprising an elongate outer column member secured to the hull member and an elongate inner column member having its upper end portion projecting above the outer column member and secured to said platform and extending into the outer column member, said outer column members having a length to project above the surface of a water body when the hull member is submerged therein to rest on the underlying land, said inner column member having its lower end closed, a separate body of liquid confined within each of said outer column members buoyantly supporting the inner column member inserted therein, and means for varying the levels of the liquid bodies in said outer column members to correspondingly extend and retract the inner column members relative to the outer column members.

6. A marine foundation structure according to claim 5 including means for securing the inner and outer column members to each other when in relatively extended positions.

7. A marine foundation structure according to claim 5 wherein the diameters of the inner column members range from about 50% to 95% of the internal diameters of the respective outer column members.

8. A marine foundation structure according to claim 5 including means for ballasting the inner column members.

9. A marine foundation structure according to claim 5 wherein the inner column members have their upper portions substantially reduced in diameter with respect to their lower portions.

10. A marine foundation structure, comprising, a hollow submergible hull member having ballasting means for submerging and refloating the same, a working platform, and a plurality of laterally spaced telescopic column units connecting the hull member to the platform for adjustably elevating the platform relative to the hull member, each of said column units comprising an elongate outer column member secured to the hull member and an elongate inner column member having its upper end portion projecting above the outer column member and secured to said platform and extending into the outer column member, said outer column members having a length to project above the surface of a water body when the hull member is submerged therein to rest on the underlying land, said inner column member having its lower end closed, a separate body of liquid confined within each of said outer column members buoyantly supporting the inner column member inserted therein, and means for varying the amount of ballast in the inner column members to correspondingly extend and retract them relative to the outer column members.

11. A marine foundation structure according to claim 10 including means for securing the inner and outer column members together when in their relatively extended positions.

12. A marine foundation structure, comprising, a hollow submergible hull member having ballasting means for submerging and refloating the same, a plurality of hollow columns mounted on the hull member to project above the surface of a water body when the hull member is submerged therein to rest on the underlying land, a body of liquid confined within each of said columns, a plurality of hollow float members and extending into said columns and having their upper end portions projecting above said columns, a platform supported on said upper end portions, each of said float members being individually buoyantly supported by the body of liquid in the column into which it extends, and means for varying the depth of submergence of said float members in said bodies of liquid to thereby vary the elevation of the platform relative to the hull member.

13. A marine foundation structure according to claim

12 having an upwardly extending tubular trunk member communicating at its lower end with the interior of the hull member and having its upper end slidably projecting through said platform.

14. A marine foundation structure according to claim 12 wherein said means for varying the depth of submergence of said float members includes means for ballasting said float members.

15. A marine foundation structure, comprising, a hollow submergible hull member having ballasting means for submerging and refloating the same, a plurality of hollow columns mounted on the hull member to project above the surface of a water body when the hull member is submerged therein to rest on the underlying land, a body of liquid confined within each of said columns, a plurality of hollow float members extending into said columns and having their upper end portions projecting above said columns, a platform supported on said upper end portions, each of said float members being individually buoyantly supported by the body of liquid in the column into which it extends, means for varying the liquid levels in said columns whereby to raise and lower the platform relative to the hull member, and means for securing the float members to the columns when the float members are in raised position, said means comprising a ring-shaped connector slidably disposed about each of said float members and adapted to rest on the upper ends of said columns, and means for securing said connectors to said columns and said float members.

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