

Oct. 28, 1958

W. F. SWIGER ET AL
SUPPORT STRUCTURE

2,857,744

Filed Dec. 16, 1955

4 Sheets-Sheet 1

FIG. 1.

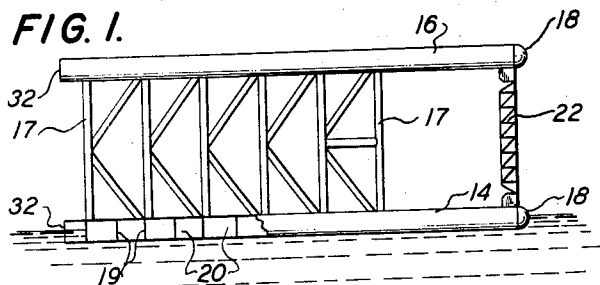


FIG. 2.

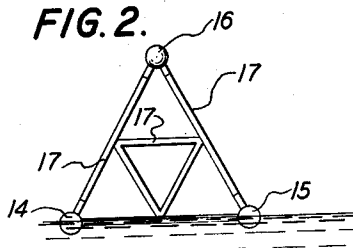


FIG. 3.

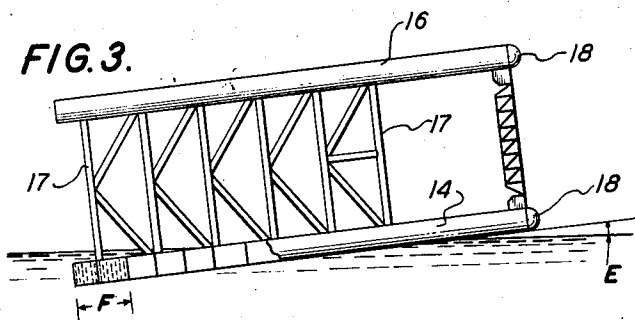


FIG. 4.

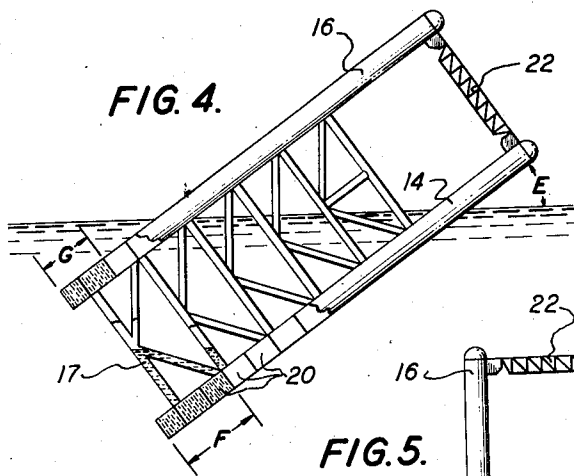


FIG. 5.

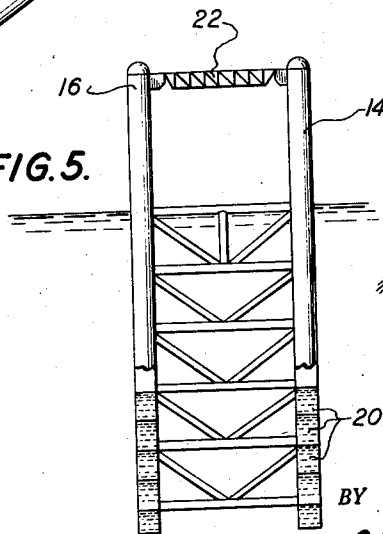
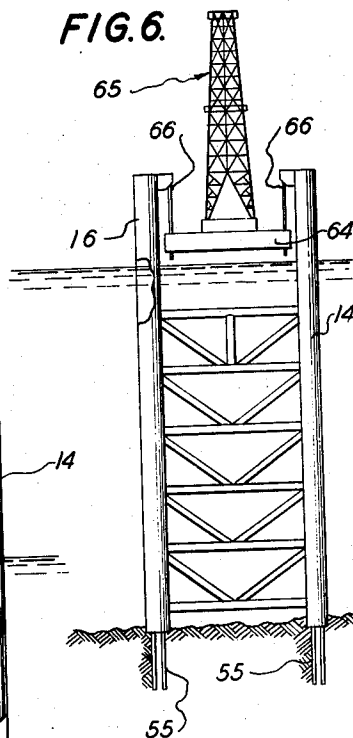


FIG. 6.



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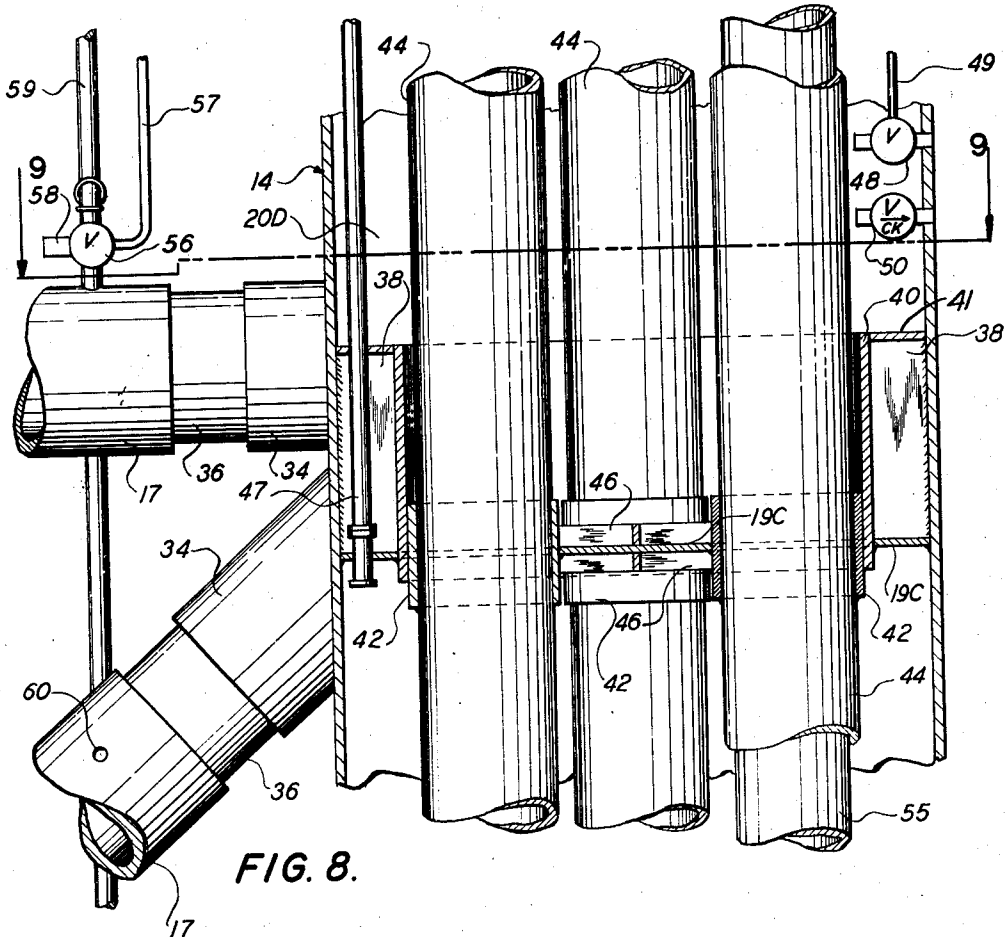
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4 Sheets-Sheet 2



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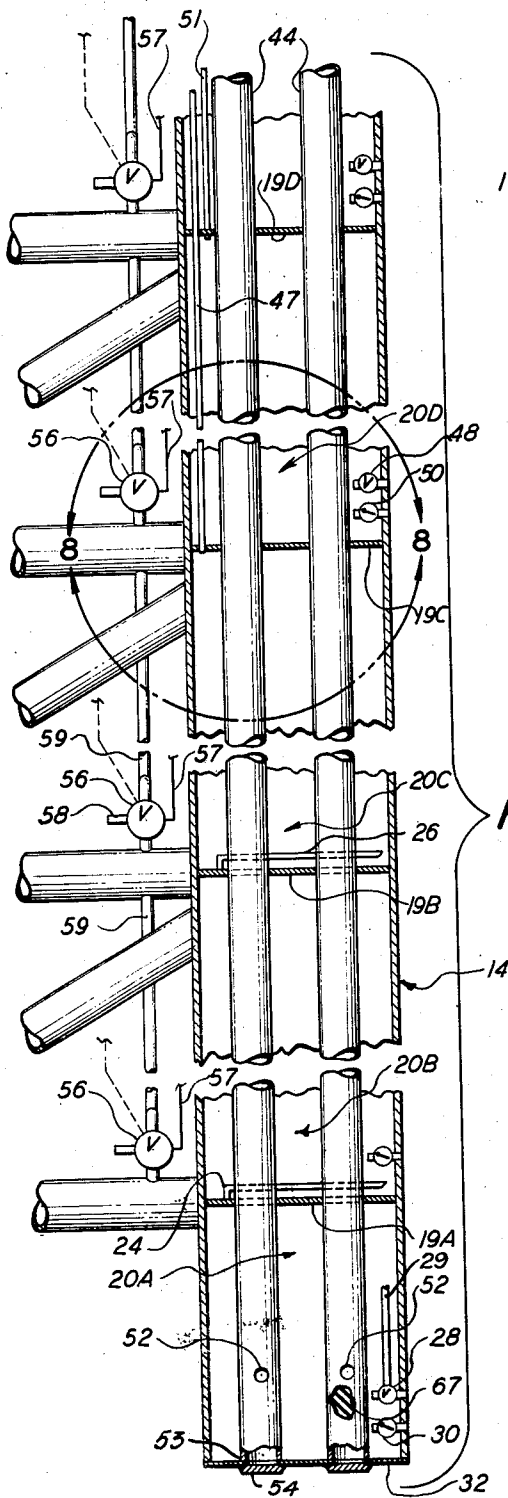


FIG. 7.

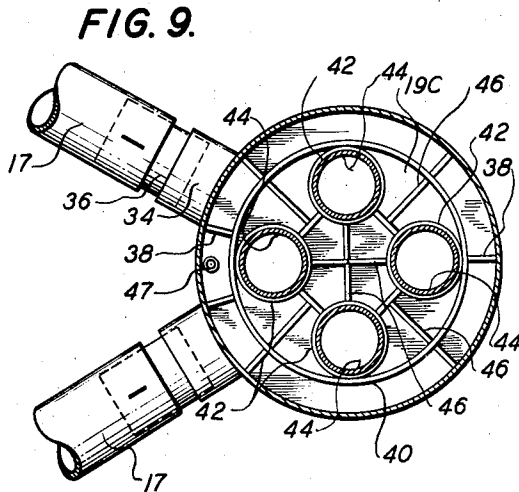


FIG. 9.

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SUPPORT STRUCTURE

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Application December 16, 1955, Serial No. 553,567

3 Claims. (Cl. 61—46.5)

This invention relates to structures for use in a body of water.

U. S. Patent 2,586,966 describes an elongated support structure adapted to be floated horizontally in a body of water and towed to a desired location. The structure is also adapted to be flooded at one end at a controlled rate so that the flooded end sinks and tilts the structure to an upright or vertical floating position. Flooding of the structure is then continued until it sinks and rests firmly on the bottom of the body of water.

This type of structure is ideally suited for supporting various types of equipment above a body of water. For example, it can be used to support drilling equipment for offshore wells, or it can be used to support electronic equipment such as that used for offshore radar stations. The structure has the advantage that it can be dewatered and tilted from a vertical to a horizontal position so that it may be towed easily from one location to another.

More particularly, the structure described in the patent is a tripod having three parallel tubular and compartmental legs connected together by cross-bracing so that each leg is equidistant from the other two. As described in the patent, the structure is adapted to be floated with two of the legs horizontal in the water while the upper or third leg rides above the water level. In this position the structure is stable and may be readily towed in the water to a desired underwater location. On reaching the location the ends of the two legs in the water are flooded so that the end of the tripod which is to rest on the bottom begins to submerge, the intention being to have the tripod structure tilt gently and smoothly from a horizontal to a vertical position.

However, the disadvantage of the structure is that after it is sufficiently flooded to start to tilt from the horizontal, it passes through a critical angle at which the moment tending to cause the structure to tilt to a vertical position begins increasing rapidly as the structure tilts toward the vertical position. Unfortunately, the structure gathers speed in tilting before the upper or third leg enters the water so that when this leg does contact the water, the structure is moving with sufficient velocity to cause the upper leg to strike the water with severe force, endangering both the structure and the personnel conducting the tilting operation.

A similar difficulty is encountered when the structure is dewatered to tilt it from a vertical to a horizontal position. As the structure nears the horizontal position, it moves into an unstable position from which it moves swiftly to a horizontal position.

This invention provides an improved support which can be tilted slowly and safely either from a horizontal to a vertical position, or vice versa.

Briefly, the invention contemplates an elongated support adapted to be floated horizontally in a body of water and tilted and submerged to rest in an upright posi-

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tion on the bottom of the water. The support includes a first set of legs adapted to float on the water when the structure is horizontal. At least one other upper leg is connected to the first set of legs by bracing members so that the other leg is supported above the water level when the support is floated horizontally. Means are provided for imparting a moment to the structure to cause it to tilt toward a vertical position, and buoyancy means are attached to the structure to exert a force opposing the tilting prior to the entry of the upper leg into the water.

In the preferred embodiment, a buoyancy member is attached to the support to be disposed above the water when the support is floated horizontally, and be carried into the water ahead of the other leg as the structure is tilted from its horizontal position. As the structure is tilted toward the vertical, the buoyancy member is progressively submerged to contribute a buoyant or lifting effect to counteract the tendency of the structure to develop an increasing moment which would cause the structure to tilt with increasing velocity until the upper leg enters the water. Thus, the buoyancy member restrains the structure from sudden or rapid movement, permitting the upper leg to enter the water smoothly and gently.

The buoyancy member may take many forms, for example buoys or barges may be used to support the sinking ends of the first set of legs, but in the presently preferred arrangement, at least some of the bracing members which hold the legs of the structure together are hollow and capable of being filled or emptied during the tilting of the structure to either a vertical or horizontal position. These buoyant bracing members extend upwardly from the two legs floating horizontally in the water, and as the legs are tilted toward a vertical position the bracing members are submerged to contribute a buoyant effect which counteracts the tendency for the structure to move swiftly toward a vertical position. The rate at which the structure tilts is easily controlled by adjusting the rate at which the buoyant braces are permitted to flood.

These and other aspects of the invention will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings in which:

Fig. 1 is a schematic side elevation, partially broken away, of the presently preferred form of the support floated horizontally on a body of water;

Fig. 2 is a schematic end view showing the support shown in Fig. 1;

Fig. 3 is a schematic side elevation, partially broken away, showing the structure of Fig. 1 with the legs in the water being flooded at one end to cause the structure to tilt toward the vertical position;

Fig. 4 is a schematic side elevation, partially broken away, showing the structure of Fig. 1 tilted sufficiently so that the upper leg enters the water and is partially flooded;

Fig. 5 is a schematic elevation, partially broken away, showing the structure of Fig. 1 in a vertical position, all three legs being flooded an equal amount;

Fig. 6 is a schematic elevation, partially broken away, showing the structure of Fig. 1 resting firmly on the bottom with all legs flooded approximately to the water level, and a drilling rig mounted on a platform supported on the upper end of the structure;

Fig. 7 is a schematic partial sectional elevation of one of the legs of the structure;

Fig. 8 is an enlarged view taken on line 8—8 of Fig. 7 and showing the details of the internal construction of the legs;

Fig. 9 is a view taken on line 9—9 of Fig. 8;

Fig. 10 is a graph showing the characteristic tilting

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moments developed by the structure when constructed with one set of dimensions, and when no buoyancy members are included as contemplated by this invention; and

Fig. 11 is a graph showing the characteristic tilting moments developed by the structure when constructed with another set of dimensions, and when no buoyancy members are included as contemplated by this invention.

Referring to Figs. 1 through 6, the support comprises a pair or first set of parallel tubular legs 14, 15 (see Fig. 2) which are designated the lower legs, since these legs are adapted to float in the water when the structure is in a horizontal position. An upper or third leg 16 is connected to each of the two lower legs by hollow tubular bracing members 17 so the upper leg is parallel to and equidistant from the other two legs. The tubular members are arranged in a K-brace system and the two lower legs are connected to each other by an identical arrangement so that each leg is equidistant from the other two. The upper end of each leg (when vertical) is sealed with a removable cap 18.

Transverse partitions or diaphragms divide each leg into a plurality of compartments. Starting at the lower end of each leg (when vertical) the diaphragms are designated 19A, 19B, 19C, 19D, etc. in ascending order, and the compartments are similarly designated 20A, 20B, 20C, 20D, etc. The compartments and means for flooding and emptying them are described in detail in connection with Figs. 6 through 9.

A temporary truss 22 is mounted across the ends of the legs which will be the upper ends when the structure is in an upright position. Unless otherwise indicated, throughout the remainder of the description the terms "upper" and "lower" are used to indicate relative positions when the structure is in an upright position.

Referring to Figs. 7 through 9, leg 14 is shown in detail, and since all three legs are identical, a description of this leg will suffice for the other two. As stated above, the leg is provided with a plurality of transverse diaphragms 19A, 19B, etc. dividing the leg into separate compartments 20A, 20B, etc. Compartment 20A is connected to compartment 20B by means of a conduit 24 extending through the upper (when the leg is in a horizontal position) edge of diaphragm 19A for a relatively short distance into compartment 20B and then turning down parallel to diaphragm 19A to terminate at the lower edge thereof. A similarly located conduit 26 connects compartment 20B with compartment 20C. Compartment 20C is not connected with the compartment above it, and the compartments 20A, 20B, 20C comprise a typical "section" in the leg, which may be made up of as many sections as necessary to accommodate various water depths.

A valve 28 within the lower end of compartment 20A is adapted to be controlled by a pneumatic line 29 extending to the upper end of the leg to admit water to compartment 20A. A check valve 30 adjacent and below valve 28 is arranged to let water out of compartment 20A when air pressure is applied to the "section" as described below. The lower end of leg 14 is closed with a cover plate 32.

Referring to Figs. 8 and 9 the diaphragm 19C is welded across the interior of leg 14 at the point where the lower tubular bracing member 17 is connected to the leg by means of an external socket 34 welded to the leg and a coupling 36, welded into the socket and the end of the bracing member. The bracing members are secured to each other intermediate the legs by similar couplings. A plurality of longitudinal ribs or stiffeners 38 are welded to the inside of leg 14 and to the top of diaphragm 19C to extend radially inwardly a relatively short distance. A stiffener ring 40 slightly longer than the ribs is welded at its outer periphery to the ribs so that its upper end projects slightly above the ribs, and its lower end projects through and slightly below diaphragm 19C to which

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it is welded to form a fluid-tight seal. A horizontal ring 41, in line with the center line of the horizontal upper bracing member 17 of Fig. 8, rests on the upper ends of the ribs and is welded at its outer periphery to the inner wall of the leg and at its inner periphery to the outside of stiffener ring 40.

Four short, symmetrically spaced pile guide sleeves 42 extend vertically through the diaphragm 19C inside the stiffener ring 40 and are welded to the diaphragm to effect a fluid-tight seal. A separate tubular pile guide 44 disposed longitudinally through each pile guide sleeve extends throughout the length of the legs and is welded to its respective pile guide in each diaphragm to effect fluid-tight seals for the compartments. The portion of diaphragm 19C within stiffener ring 40 is reinforced with webs 46. An air line 47 extends through diaphragm 19C to the upper end of the structure and is adapted to receive compressed air from a supply (not shown) to pressurize the compartments below diaphragm 19C when dewatering of that portion of the leg 14 is required.

A valve 48, controlled by a pneumatic line 49 extending inside the leg to the upper end of the structure, is located on the inside wall of leg 14 above diaphragm 19C, and is adapted to flood compartment 20D. A check valve 50 is located just below valve 48 on the inside wall of leg 14 and is arranged to let water flow out of compartment 20D when pressurized with air through an air line 51 extending from the upper end of the leg through diaphragm 19C and opening into compartment 20D (see Fig. 7). Both of the valves are located on the side of leg 14, which is lowest when the structure is floated in a horizontal position.

The upper end of each pile guide terminates just below the upper end of each leg. The lower end of each of the pile guides (see Fig. 7) is provided with holes 52 to vent the interior of the pile guides to compartment 20A, and the lower end of each pile guide is welded to the upper surface of the cap 32 around an opening 53 in the cap. A separate cover plate 54 of a diameter slightly larger than that of the openings 53 is welded to the bottom surface of the cap 32 to maintain the fluid-tight integrity of the leg. The cover plates are lightly welded to the cap so that they are readily knocked off by piles 55 (see Fig. 6) which may be driven down through the pile guides and out the lower end of the legs as shown in Fig. 6 when the structure is to rest on a soft bottom.

The lower "sections" of the structure, say the bottom 40 to 60 feet, are provided with conduits 24, 26 arranged as described above. The upper "sections" of the structure, that is, the "sections" which ordinarily will not be flooded until the structure is in an upright position, need not necessarily have conduits so arranged. The diaphragms within the upper "sections" may simply be provided with ports to pass air or water, the diaphragms dividing the "sections" being as described for diaphragms 19C, 19D.

Each of the tubular cross-bracing members 17 are provided with means at their opposite ends to let air or water either in or out. For example, as shown in Fig. 8, the upper bracing member is provided with a three-way pneumatic valve 56 having a pneumatically control line 57 extending to the surface. Valve 56 may be set to let water into the bracing through a conduit 58 or set so that air can be forced into the bracing member from a manifold 59 extending to a source of compressed air (not shown) at the upper end of the structure. A similar valve is provided at the opposite end of the bracing member.

A more simple arrangement for flooding and dewatering the bracing members is shown in the lower bracing member of Fig. 8, which is provided at opposite ends with a separate orifice 60 of a predetermined size to let water into the bracing at a controlled rate as the leg is submerged. Water drains out the orifice as the leg is reflooded.

The operation of the structure is understood most readily from reference to Figs. 1 through 6 and Fig. 10. As indicated in Fig. 4, the dimension F represents the amount of flooding of the two lower legs measured from their lower ends, and the dimension G represents the amount of flooding in the upper leg measured from its lower end.

The curves of Fig. 10 show the tilting characteristics developed by a tripod structure built as described above, the legs each being twelve feet in diameter, and made from steel plate which varies in thickness as follows: 1 in. starting at the top of the leg and gradually increasing to 1 1/4 in. at about 10 feet above the first bracing member, the next 30 feet being 1 1/4 in. the next 60 feet 1 in. the next 60 feet 3/8", and the remainder of the plate in the leg 3/4 in. The legs are spaced on 125-foot centers, the overall length of the legs being 295 feet. The tubular cross-bracing is 3 feet in diameter, and made from 3/8 in. steel plate. The "K" pattern of the bracing is set at 40-foot intervals. The pile guides are 3 feet in diameter and are made from 1/4 inch steel plate.

The tilting moments shown in Fig. 10 are those which would be developed if the cross-bracing were not buoyant, that is, the curves represent the moments which would be developed if I-beams, for example, of corresponding mass were used instead of tubular members. As shown in Fig. 10 the moment which causes the structure to tilt toward the vertical is arbitrarily assigned a negative value, while the moment which causes the tilt toward the horizontal is assigned a positive value.

With the structure in the horizontal position shown in Fig. 1, the angle E between the longitudinal axis of the structure and horizontal is zero. In this position, the center of gravity is vertically above the center of buoyancy of the structure, and the structure is in a stable position.

To tilt the structure from a horizontal to a vertical position, a controlled amount, say 40 feet, of water is admitted to the end of each of the lower legs which is to rest on the bottom. Referring to Fig. 10, F is now 40 feet and the structure starts tilting toward an upright position. In the initial stages of flooding the two lower legs to start the structure tilting toward the vertical, the conduits 24, 26 in the diaphragms 19A, 19B, insure that each compartment is completely flooded before flooding of the superadjacent compartment begins. Thus, substantially no air is trapped in the compartments and the flooding of the structure proceeds in an orderly and predictable manner.

If the cross-bracing did not exert a buoyant effect as the structure tilts, the negative moment, that is, the moment tending to cause the structure to tilt to a vertical position would increase rapidly as the structure tilts. The curves 61, 62 and 63 on the graph show the moments developed by the structure when the lower legs are flooded by amounts of 35, 40 and 45 feet respectively. As can be seen from the graph, the greater the length flooded, and the more the structure tilts toward the vertical (up to angle E equalling about 25 degrees, which is the angle at which the third leg enters the water), the greater the negative moment developed by the structure. The rate at which the tripod tilts is proportional to the radial distance from the arc representing zero moment to the curves 61, 63. Following curve 62 ($F=40'$), if there were no buoyancy members to oppose the negative moment developed by the tilting structure, the structure would tilt with increasing speed until the negative moment developed exceeded about 40 million pound feet and the upper or third leg smashed into the water. This is indicated as point A on the graph. Further tilting of the structure would submerge the third leg which in effect adds positive moment to the structure and reduces the negative moment of the structure along curve 62 in the direction indicated by the arrow to point B, that is, until

zero moment is developed and the structure is in a stable position with angle $E=28^\circ$.

Tilting of the structure in the manner just described, which would be dangerous to personnel and equipment, is avoided by virtue of the buoyant cross-bracing members. With the structure of the invention, the cross-bracing members at the end of the structure which is to rest on bottom are submerged as the structure begins to tilt so that their buoyant effect counteracts the tendency for the structure to develop a large negative moment. By controlling the flooding of the cross-bracing members, the structure is tilted slowly and gently to ease the third leg into the water at any desired rate. In effect, the negative moment is held to a value very close to the curve in Fig. 10 which represents zero moment. Thus, the structure can be brought to point B on the graph virtually down the zero moment curve, and at a correspondingly slow rate of tilting.

From point B the two lower legs are flooded to 60 feet ($F=60'$) to bring the structure to point C on the curve representing zero moment, the structure tilting from about 28° to 32° . This tilting further submerges the upper leg so that the moment of the structure remains zero, that is, it is stable and does not tend to tilt further. Flooding of the two lower legs to about 60 feet insures stability of the structure as it moves toward the vertical position.

While maintaining the amount of flooding in the lower legs at 60 feet, water is gradually admitted to the third leg until this leg also contains 60 feet of water as shown in Fig. 5. The movement of the structure is indicated on the graph by following the curve representing zero moment. Thus, when the third leg has been flooded to a depth of 40 feet ($G=40'$), the structure is at an angle of 50° to the vertical. Further flooding of the third leg to 60 feet swings the structure to a vertical position while drawing 193.1 feet of water.

All three legs are then gradually flooded to approximately the water level to seat the structure firmly on the bottom. The caps 18 are removed from the upper end of each leg, and if a soft bottom is encountered, piles 54 are then driven by means of the temporary truss through the pile guides in each leg to anchor the structure firmly in place. If the structure is to be used for drilling, a floating barge 64 carrying a drilling rig 65 is then floated into the space between the upper ends of the legs and hoisted above the water line on support rods 66. Drilling operations may then begin.

To remove the structure, the platform is lowered and towed away, the piles are disengaged at their lower ends below the lower ends of the legs of the structure, either being decoupled, jettied free, or cut by suitable means, such as shaped charges. The lower ends of the pile guides are plugged with a packer 67 (see right hand pile guide in Fig. 7), the caps 18 are replaced and the legs are then dewatered in reverse order from that described above. Recovery of the structure proceeds in the reverse direction along the curves just described.

All legs are dewatered until 60 feet remains in each leg, that is, F and G each equal 60 feet.

The upper or third leg is then dewatered. As the dewatering proceeds, the structure tilts toward the horizontal until when the upper or third leg is completely emptied of water. The structure is then at point C in Fig. 10 at an inclination of about 32 degrees from the horizontal. Further dewatering of the two lower legs is then started. The structure moves upwards, tilting more nearly to the horizontal. Rotation during the initial stages is controlled by the rate at which the two lower legs are dewatered. Then the structure moves smoothly to the position of floating horizontally on the surface. Velocity of the structure during this latter period is controlled by the rate at which the bracing-members are permitted to drain.

The structure just described is relatively large and

designed for use in water about 200 feet deep or deeper. For shallower water a slightly different problem is encountered in tilting the structure. For example, a structure having an overall length of only 165 feet, and otherwise being constructed exactly as described for the preceding structure, is adapted for use in water of a depth of about 80 feet to 125 feet. The tilting characteristics of this smaller structure are shown in the curves of Fig. 11 in which data are presented in a manner similar to that shown in Fig. 10. When the lower legs in this shorter structure are flooded to a depth of about 30 feet ($F=30'$), the structure begins tilting toward the vertical. If the buoyant cross-bracing were not present the negative moment would increase quickly as shown by curve 68, and the structure would tilt with increasing speed until the two lower legs struck the bottom. This would occur before the upper or third leg enters the water, and the structure would have developed such momentum that serious damage would be likely to occur. However, as with the structure described above, tilting of the structure at a slow and careful controlled rate is achieved by gradual flooding of the buoyant cross-bracing members.

As shown in Fig. 11, even after the two lower legs touch the bottom (indicated as point M), there is considerable negative moment remaining and as the cross-bracing members are flooded, the structure continues to tilt toward the vertical and comes to rest at the position indicated by point N in Fig. 10.

In this position, sufficient weight of the structure rests on the bottom so that the structure is not lifted with passing waves. Thus, instead of pounding on the bottom, the structure simply rocks with any waves which may be present. The angle at which the structure comes to rest depends upon the amount of flooding of the two lower legs, since this controls the position of the center of gravity. For example, with the two lower legs flooded so that $F=30'$ the structure is at an angle of about 54° to the horizontal.

The third leg is then flooded slowly and the structure tilts slowly to the vertical and comes to rest with all legs seated on the bottom. All legs are then flooded to approximately the water level and piles are driven, if needed, as described previously to anchor the structure firmly in place.

The procedure for tilting the smaller structure to the horizontal position is also different from that described for the large structure, because the short structure has a position of almost upright stability in the water with all legs completely dewatered.

To tilt the short structure to the horizontal position, all auxiliary equipment is removed from the structure. The piles are released and removed as described previously, and the legs are made water-tight at each end. The third leg is then completely dewatered, causing the structure to tilt toward the horizontal. The two lower legs are then completely dewatered at a uniform rate. The structure then assumes a stable position at an angle of about 62° to the horizontal, indicated as point P in Fig. 11. In this position the lower end of the third leg is at the surface of the water. To overcome the condition, a sufficient number of cross-bracing members of the short structure are provided with a valve and pres-

surizing system similar to that shown on the upper cross-bracing member in Fig. 8, so that the cross-bracing members can be dewatered to give the structure the necessary additional buoyancy to bring it to the surface in a horizontal position. The cross-bracing members are then dewatered, returning the structure to a horizontal position.

We claim:

1. An elongated support structure for extending from the bottom of a water body to above the surface of the water comprising three hollow legs each including closure means to form water-tight regions, means supporting the legs in parallel and equally spaced relation to form a rigid structure adapted to float horizontally in the water on two of the legs with a single leg supported between the other two and above the water surface, a hollow water-tight tubular member extending from each of the two legs to the third leg adjacent one end of the legs so as to extend upwardly free of the water when the structure is floating horizontally, and means for selectively and separately flooding the three legs beginning at said one end thereof.

2. An elongated support structure for extending from the bottom of a water body to above the surface of the water comprising three hollow legs each including closure means to form water-tight regions, means supporting the legs in parallel and equally spaced relation to form a rigid structure adapted to float horizontally in the water on two of the legs with a single leg supported between the other two and above the water surface, hollow water-tight tubular members extending from the two legs to the third leg adjacent one end of the legs so as to extend upwardly free of the water when the structure is floating horizontally, means for selectively and separately flooding the three legs beginning at said one end thereof, and separate means for flooding the hollow tubular members as the structure rotates in the water to immerse the tubular members.

3. An elongated support structure for extending from the bottom of a water body to above the surface of the water comprising three hollow legs, including spaced closure means forming a series of compartments in each leg, means supporting the legs in parallel and equally spaced relation to form a rigid structure adapted to float horizontally in the water on two of the legs with a single leg supported between the other two and above the water surface, hollow water-tight members extending from the two legs to the third leg adjacent one end of the legs so as to extend upwardly free of the water when the structure is floating horizontally, means for selectively and separately flooding and deflooding the compartments in the three legs beginning at said one end thereof, and separate means for flooding and deflooding the hollow tubular members.

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