June 29, 1965 M. LUDWIG 3,191,388

SLENDER COLUMN SUPPORT FOR OFFSHORE PLATFORMS

Filed Nov. 8, 1962 3 Sheets-Sheet 1

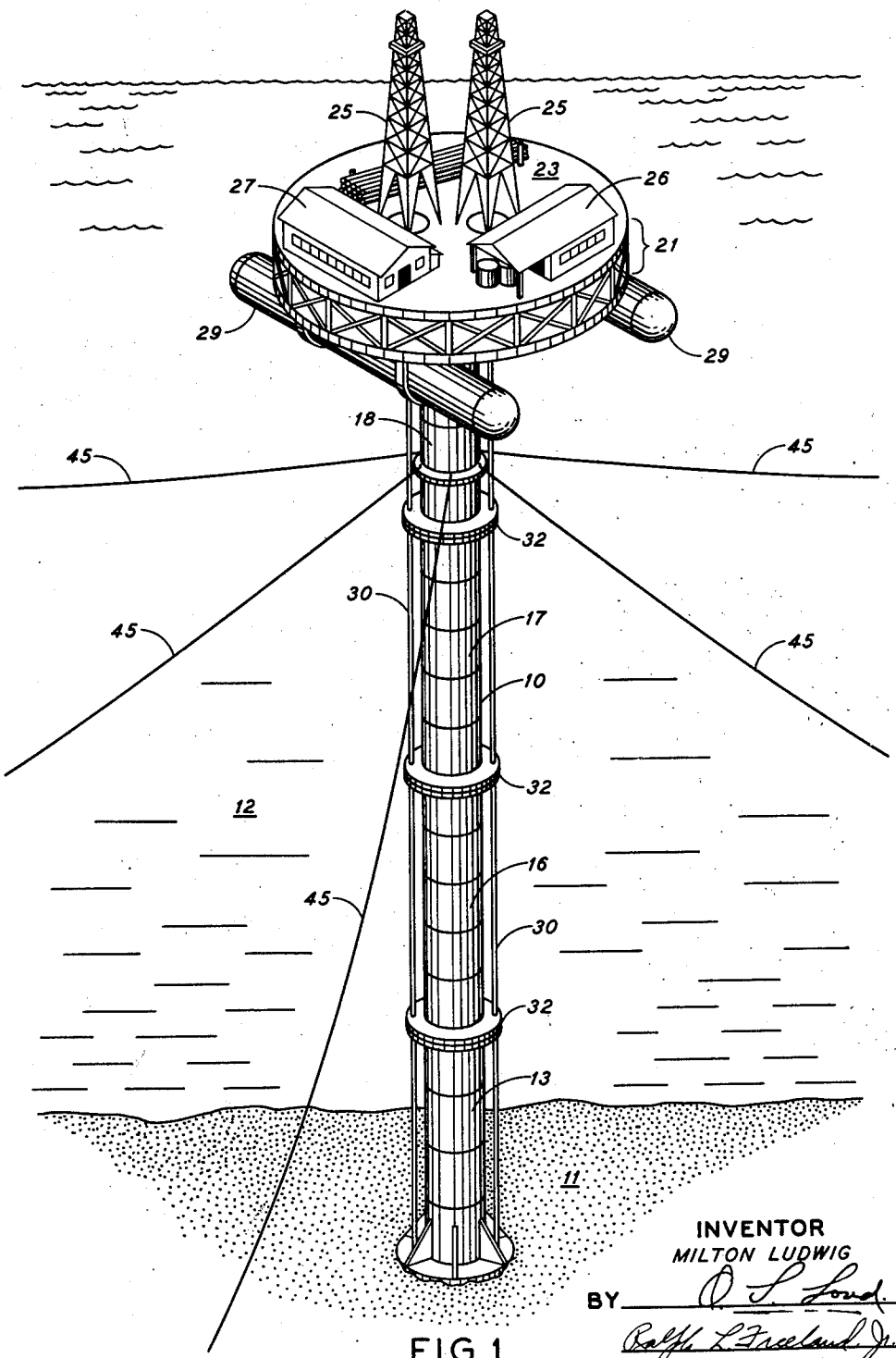


FIG. 1

INVENTOR
MILTON LUDWIG
BY O. L. Loud
Ralph L. Freeland Jr.
ATTORNEYS

June 29, 1965 M. LUDWIG 3,191,388

SLENDER COLUMN SUPPORT FOR OFFSHORE PLATFORMS

Filed Nov. 8, 1962 3 Sheets-Sheet 2

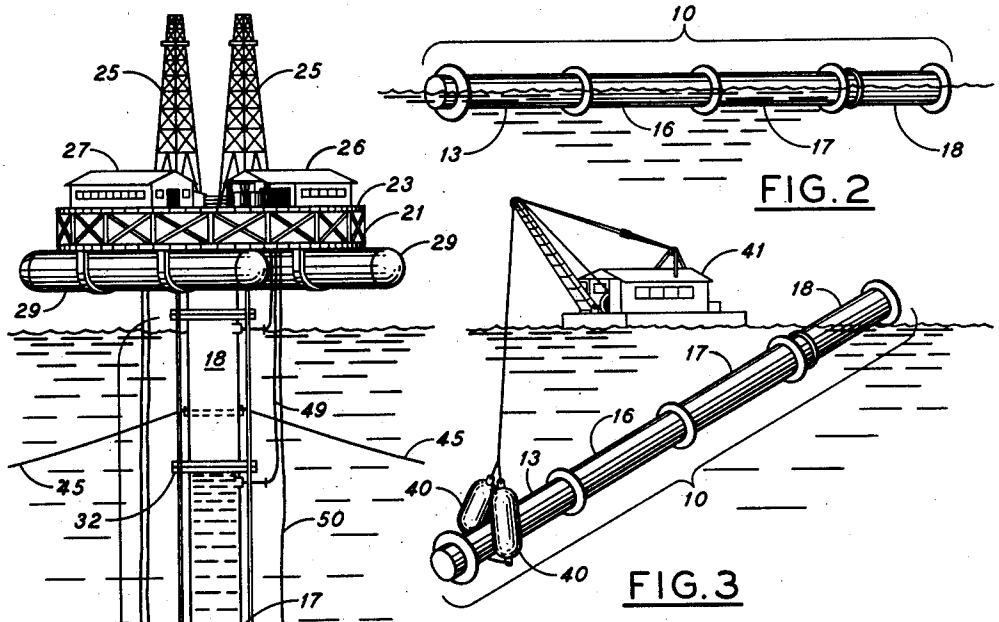


FIG. 2

FIG. 3

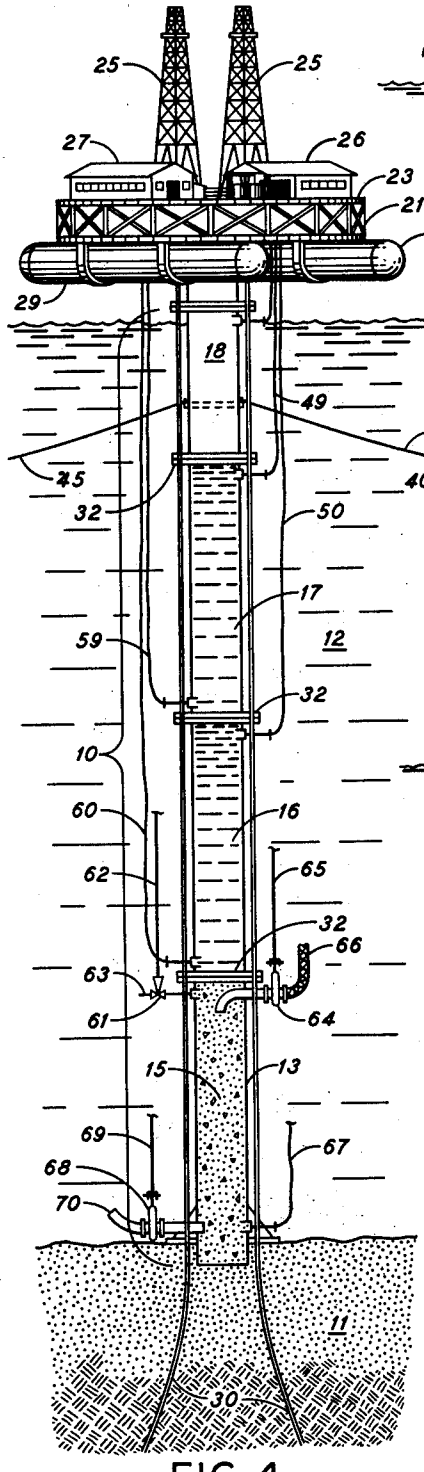


FIG. 4

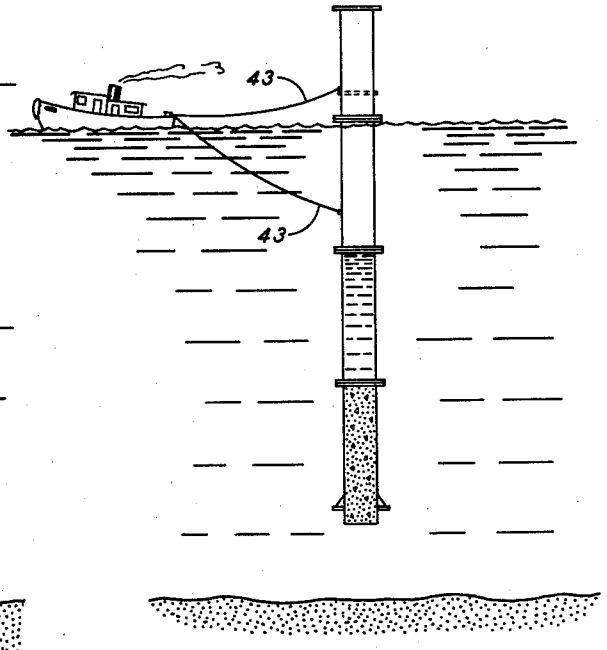


FIG. 5

INVENTOR
MILTON LUDWIG
BY O. L. Ford.
Ralph L. Freeland Jr.
ATTORNEYS

June 29, 1965 M. LUDWIG 3,191,388

SLENDER COLUMN SUPPORT FOR OFFSHORE PLATFORMS

Filed Nov. 8, 1962 3 Sheets-Sheet 3

FIG. 6

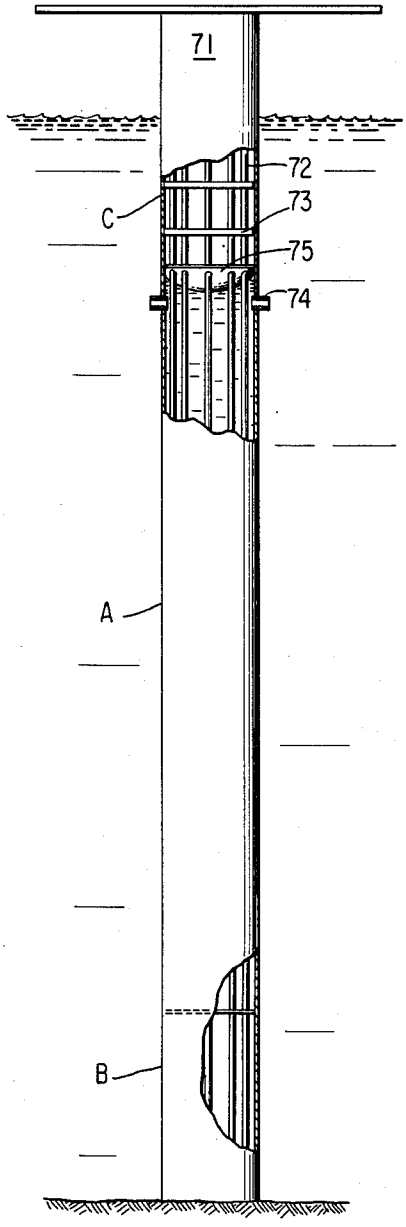
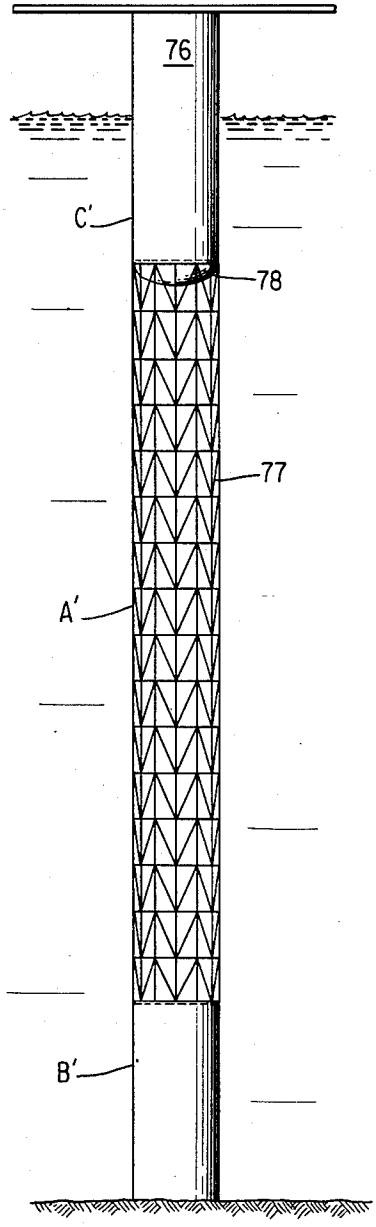


FIG. 7



United States Patent Office 3,191,388 Patented June 29, 1965

3,191,388

SLENDER COLUMN SUPPORT FOR OFFSHORE PLATFORMS

Milton Ludwig, Berkeley, Calif., assignor to California Research Corporation, San Francisco, Calif., a corporation of California

Filed Nov. 8, 1962, Ser. No. 236,774
8 Claims. (Cl. 61—46.5)

This application is a continuation-in-part of application Serial No. 606,276 filed August 27, 1956, and now abandoned.

The present invention relates to deep-water offshore platforms and more particularly to columns for supporting an offshore work platform of the mobile type.

The invention has for a particular object providing a work platform supported above an underwater site on a slender, single, elongated and rigid supporting column, generally cylindrical in form, having a greatly increased ratio of length to diameter, at least the lower portion of said slender column having a density greater than water, its central portion having substantially the same density as water, and its upper portion having less density than the surrounding water, so that said slender elongated column has the compressive load on its central portion reduced so as to increase the vertical stability thereof to support a work platform in waters of greater depth than has heretofore been possible.

In the construction of offshore work platforms it has been common practice to assemble a tower-like structure of steel beams in an open network or a system of multiple columns that extends from the underwater bottom to a point above the water line. In such structures it is difficult to obtain lateral stability due to the great amount of weight positioned at the upper end of a relatively narrow structure. These types of structures are particularly susceptible to wave forces. Additionally, their high cost of erection at an offshore location has made it uneconomical to use such structures in waters deeper than about 300 feet. The assembly of sectionalized towers and open frameworks is, of course, a very complicated and expensive operation, since generally each section must be assembled at the work site. While it has been proposed to preassemble open tower structures and then tow them to the work site, excessive power is required to tow these complex structures at any reasonable speed. Likewise, favorable weather and wave conditions are required for such towing operations.

In accordance with the present invention there is provided a stable work platform, or drilling structure, that can be preassembled and moved either from the original construction site to a first work site, or from one work site to another. Likewise, such structures can be used in water depths up to about 1,000 feet.

In accordance with the invention, the work platform is desirably supported upon a single slender cylindrical column of generally uniform diameter, extending from the underwater bottom to a working height above the expected upper level of wave action. Vertical stability of the relatively slender column is attained to a large degree by compartmenting the column into at least three vertically separated portions of different densities. Desirably the upper compartment, including that portion extending above the water surface has a working density less than that of the surrounding water, so that the upper portion acts as a floating, or buoyant element. The bottom section of the column, that is, the part in contact with underwater bottom, can be given a working density

greater than the surrounding water. Such density is supplied by filling the lower part of the column with rock, sand or concrete. The central compartment of the column is left full of water when the structure is in its normal operating position, so that said compartment has essentially neutral buoyancy. By this unique arrangement of different densities in the upper center and lower portions of the support column, the support structure, and in particular its central section, may be placed in vertical tension. Thus the column is made stable in a vertical position during the construction period, before permanent guys are attached to hold said column on location. This condition prevails even under lateral loading effects applied by wave and wind forces on the column. Further, by the provision of a single columnar design for the supporting structure there is reduced to a substantial extent the unpredictable effects of wind and wave forces acting on the supporting structure. Thus, when the lower end is seated on bottom the platform may be held in a relatively stable vertical position with a minimum of anchor lines, even in deep water.

In accordance with a preferred method of assembling the foregoing structure, comprising at least three separated compartments, desirably the entire column is assembled on shore to the required length for the proposed erection site. Before launching said column into the water, each of the three compartments can be sealed and empty so that the entire structure is buoyant and will float in a relatively horizontal position on the surface of the water. Thus, the elongated structure may be readily floated through shallow waters into deep water areas. After arrival in deeper waters, and in particular, on arrival at the first work site, the end of the column selected as the base is sunk to bottom by admitting water to said compartment. The upper portion is preferably maintained sealed so that the structure remains floating in a vertical line, with the upper end extending out of the water. The vertically oriented structure is then floated into the desired position over the underwater work site. The middle portion is then permitted to fill with water so that the bottom sinks and the column assumes a vertical position on the work site. Either before or after the center portion is filled with water, the bottom portion is filled with rock, sand, gravel or the like, to weight said portion and give it a density greater than the surrounding water. Thus the column is landed on the work site with the upper portion buoyant, the lower portion negatively buoyant, and the center of the column under tension. Such initial tension through the center of the column neutralizes to large degree the tendency of a long, slender column to buckle under subsequently applied vertical and lateral loads.

Further in accordance with the invention, advantage can be taken of the upper, or buoyant, compartment in the column during the erection period to assure that the column seats firm on bottom. For this purpose water may be admitted to the upper chamber, after the lower and middle chambers have been filled, to increase temporarily the weight of the column on bottom and assure penetration of the unconsolidated sediments. The water in the upper chamber is then expelled to provide the desired buoyant compartment in the structural column. Final installation of said column in deep water desirably includes the positioning of guy lines around the periphery of the column to restrain it from movement under the lateral load applied by wave action.

In completing the work structure, a platform, desirably circular, is floated to location and elevated to the top of the portion of the column extending out of the

water. In practice, this platform is positioned sufficiently above the water's surface to avoid action of storm or tidal waves.

Further objects and advantages of the present invention will become apparent from the following description when read in conjunction with the accompanying drawings, which form an integral part of the present specification.

In the drawings:

FIG. 1 is a perspective view of one form of underwater work platform constructed in accordance with the present invention;

FIG. 2 is a schematic view of the support column of FIG. 1 illustrating its position after initial inshore assembly, preparatory to movement to an underwater work site;

FIG. 3 illustrates a preferred method of lowering the support column from the position illustrated in FIG. 2 to that shown in FIG. 5;

FIG. 4 is a vertical elevation view of the dynamically stable column illustrated in FIG. 1 partially in section to illustrate the interior of the column when on the work site;

FIG. 5 illustrates the position intermediate FIG. 3 and FIG. 4 and shows the preferred method of moving the vertical column from one work site to another, after disassembly of the work platform from the top of the column and partial refloating of the column;

FIG. 6 illustrates a column reinforcing arrangement; and

FIG. 7 illustrates a modified form of the FIG. 6 column structure.

Referring now to the drawings, and in particular to the FIGS. 1 and 4, there is illustrated a preferred embodiment of the underwater platform constructed in accordance with the present invention. As there shown, a single slender support column **10** having a ratio of length to diameter up to about 40 to 1 extends from the underwater bottom, indicated generally as **11**, to a level above the surface of the water **12**. As particularly seen in FIG. 4, slender column **10** in general comprises four sections, although for purposes of description it is best considered as having three sections; the two center sections are considered hereinafter as a single compartment.

Desirably the lowermost section **13** is arranged to be filled with sand, aggregate, or other dense material **15** so that portion **13** has substantial negative buoyancy. The center compartment, including lower central portion **16** and upper central portion **17**, is selectively filled with water so that this central section of slender column **10** has substantially neutral buoyancy. Upper portion **18** of column **10** is preferably sealed at atmospheric, or greater pressure, so that when column **10** stands in the position shown in FIG. 4 the upper section has positive buoyancy. As thus assembled, it will be seen that upper portion **18** gives slender column **10** a vertically upward component of force, thus reducing the compressive force in central portion **16**, **17** of the column, while at the same time lower portion **13** gives the column a downward component of force. It will be seen that the compressive force on column **10** is therefore reduced throughout a substantial portion of its length. By such arrangement of column **10**, the present invention makes possible erection of a vertically supported platform in depths upward of 1,000 feet of water with an outer diameter of about 25 feet.

As further illustrated in FIGS. 1 and 4, a unitary platform **21** of generally circular configuration is supported on the upper end of column **10** to form a work surface **23**. A plurality of drill rigs **25**, and other required drilling equipment for offshore work, such as hotel and storage facilities, as indicated by structures **26** and **27**, are mounted on work surface **23**.

In the assembly of platform **21** onto column **10**, the work structure is floated to the drilling site. For example, the platform may be self-supporting on a pair of elongated pontoon members **29**, or transported on barges or in sections. In the arrangement of FIG. 4, platform **21** is floated to location on pontoons **29** and then hoisted into its raised position by any suitable jacking arrangement.

As seen in both FIGS. 1 and 4, a plurality of conductor pipes **30** for guiding drill pipe and return of drilling fluid to the work surface are desirably supported by column **10**. In the present embodiment, flanges **32**, which structurally stiffen column **10** and separate it into compartments **16**, **17**, and **18**, are formed with eyelets for guiding conductor strings **30**.

Conductors **30** may be positioned on the inside of column **10** to add to the strength of the shell of said column. Such a structure permits a reduction in the strength of the side wall and reduces the resistance to water flow around the column in the wave action zone. The internal structure of the mast or column structure as thus constructed is somewhat more complicated than that shown in the drawings, since the mating segments forming conductor **30** must be sealed from connection with the surrounding space of the chambers in which they run.

Referring now to FIGS. 2, 3, and 5, there is illustrated a preferred method of assembling mast, or column **10** to support work platform **21** above the underwater work site. Initially each of the sections **13**, **16**, **17**, and **18** are assembled in drydock, or on land, as an elongated cylindrical column, and desirably each section is air-filled so that the column is uniformly buoyant in water. The entire column **10** is then rolled, or floated, in its horizontal position, as illustrated in FIG. 2, so that it may pass through relatively shallow waters without requiring much draft. Auxiliary float members may be used along the length of column **10**, if necessary, to reduce the draft further.

The entire assembly can then be towed into open water. Since the structure is substantially cylindrical, the power required for towing is maintained ideally low. Desirably, in relatively deep waters, say up to 1,000 feet, the diameter of cylinder **10** may be of the order of 25 feet. In shallow waters this diameter can be reduced, but desirably the column's ratio of length to diameter is not more than about 40 to 1.

After towing to the work site, or at least into deep water, lower, or bottom, chamber **13** is permitted to fill with water so that the lower end begins to sink, due to the weight of the shell. Preferably, this end of column **10** is controlled as to its rate of lowering by pontoons **40** and work barge **41**, as shown in FIG. 3. During this operation chambers **16**, **17**, and **18** are all maintained substantially buoyant. After column **10** has been turned into its vertical position, lower center compartment **16** is floated with water, the column assuming the position illustrated in FIG. 5. In this way column **10** is further lowered into the water while still in a vertical position, and suitably landed at the desired location on bottom by tow lines **43** attached to a suitable tug, or the like. When column **10** is thus properly positioned over the work site, upper chamber **17** is likewise flooded with water, to reduce further the buoyancy and bring the column into engagement with bottom, as shown in FIG. 4. At this time chamber **18** may also be at least partially flooded to increase further the weight of shell **13** on bottom, but desirably this is not done until the water in compartment **15** is displaced through valve **61** by weighting material, such as sand, rock, or gravel, supplied through line **66** and valve **64**. Valves **61** and **64** are operated by lines **62** and **65** respectively.

After vertical erection of column **10** on site, a plurality of anchor or guy lines **45** are attached radially around the upper portion of mast **10**, but below the water's surface, to hold column **10** against relatively

large lateral displacement forces. Such guy lines are, of course, not required to maintain vertical stability of the column under normal operating conditions, but are required to hold the column against overturning moments produced by wind, wave, tide, and large eccentric loads on platform **21**. The internal vertical stability of slender column **10** is increased by the tension placed throughout its central portion, represented by chambers **16** and **17**, applied by weight in chamber **13** and buoyancy of chamber **18**.

In the final stage of erection, platform **21** is positioned on the top of column **10** and jacked or elevated into a position such that both platform **21** and pontoons **29** are above the top of normally expected waves at the work site.

Upon completion of drilling operations, or other work on the platform, the column is moved to another drilling site by removal of platform **21** and guy wires **45**. Water is blown out of upper neutral buoyancy chamber **17** and, if required, from chamber **16**, so that their buoyancy will permit column **10** to raise from bottom. Desirably, water from chambers **16** and **17** is blown down by supplying compressed air to the upper part of each chamber, such as through line **49**, and control of outflowing water through line **59** from chamber **17**. Thus, the column may be raised to the position shown in FIG. 5. The column may then be towed in its vertical position to the next work site. If needed, ballast may also be removed from lower chamber **15**, as required. For this reason said ballast is desirably an unconsolidated material such as sand rather than cement or concrete.

If it is desirable to change the over-all length of column **10**, lower neutral buoyancy chamber **16** is dewatered by supplying compressed air through line **50**. Water exhausted from compartment **16** is controlled by a regulating flow through line **60**. Material in the lower or weighted end is unloaded by jetting water under pressure from line **67** through pipe **70** and valve **68** opened from the surface by line **69**. However, it may be desirable to use positive buoyancy elements, such as floats **40**, to raise this portion, without unloading it. Thus, the assembly may be brought back to its level position as shown in FIG. 2. Further chambers, sealed at either end, are then interconnected to flanged coupling member **32**. In this way the length of column **10** is variable at will, and can be changed to conform to the required height for the structure above any given underwater work site.

The work platform supporting column of this invention may be fabricated in various modes. As an example, it may be desirable to provide some form of internal column reinforcing. As shown in FIG. 6, such a reinforced column arrangement may include a cylindrical outer shell **71** which is internally supported by a plurality of tubular members **72**, which members extend longitudinally of the column **71**. Such longitudinal reinforcing members **72** in turn may be secured by vertically spaced, annular ring girders **73**.

The lower enclosed portion B of column **71** has a specific gravity substantially in excess of that of the surrounding water so as to provide a ballasting or weighting effect acting upon the lower end of the intermediate column portion A. This specific gravity results from the composite weight of the structural members of the lower column portion B and the ballasting material carried by this column portion.

The intermediate column portion A of the column **71** is maintained in tension as a result of the buoyant force imposed on its upper end by the upper, buoyant column portion C, which buoyant force is resisted by the ballasting force imposed on its lower end **75** by the lower, ballasted column portion B. Intermediate column portion A may be provided with ports such as the port **74**, by means of which adjacent water may flow into the intermediate column portion A and thus fill this portion so as to exert upward lifting force on the end **75** of column portion C. This transversely extending column divider **75**, which may be generally convex, as shown, separates the buoyant upper portion C from the intermediate portion A and defines the top of the intermediate portion A and the base of the buoyant portion C. As illustrated, the reinforcing members **72** extend through the divider **75**.

An alternative structure is shown in FIG. 7. In this arrangement the intermediate portion A′ of a column **76**, which portion exists in tension, comprises an open network **77** of conventional framing members. This open framework defines a rigid column portion connecting the lower, enclosed and ballasted column portion B′ and the upper, buoyant column portion C′.

As is apparent, the open nature of the network **77** allows water surrounding the column **76** to exert an upwardly directed lift or buoyant force on a base **78** of the upper, buoyant column portion C′. Base **78** is a column partition secured to the top of column portion A′. It may bulge downwardly into the framework interior as shown. The lifting force acting on the top of the intermediate column portion A′, together with the downwardly directed force exerted on the base of the intermediate column portion A′ by the ballasted column portion B′, is effective to maintain the intermediate column portion A′ in tension.

For handling, installing and moving purposes, where column portions are to be filled with or emptied of air, water, or ballast, the various column portions of the FIG. 6 and FIG. 7 structures may be provided with valved ports and conduit networks of the general type described in connection with the FIG. 1 apparatus.

As demonstrated, a submerged intermediate column portion may be placed in tension by a variety of techniques. Such a column portion, where cylindrical in nature, may be filled with fluid through a fluid filled conduit extending to the surface such that a substantial buoyant force is applied to the base of the upper column portion sufficient to maintain the intermediate column portion in tension. The intermediate column portion may be ported so as to provide free fluid communication with the surrounding water whereby this adjacent water may act directly on the base of upper column portion and thus apply a force to the top of the intermediate portion to place it in tension. A similar effect may be achieved by employing an intermediate column portion having an open framework.

The particular structure employed notwithstanding, the net effect of the tensioning of the middle column portion is to provide a highly stabilized column structure capable of resisting lateral deflection to an enhanced degree and having a capacity for supporting heavier vertical loads without buckling. The stabilizing of the column against lateral deflection is of particular significance. In off shore drilling sites, wave action has been found to pose a serious threat to structural stability. However, the column tensioning envisioned in this invention effectively counteracts deflection tendencies occasioned by lateral wave action.

Various modifications and changes in both the structure and method of assembly will occur to those skilled in the art. For example, several elongated cylindrical columns of lesser ratios of length to diameter may be bolted or tied together to form a support for the work platform. However, in accordance with this invention each column will comprise a positive buoyancy chamber, a negative buoyancy chamber, and a central portion having neutral buoyancy, so that the compressive forces in the central portion thereof will be reduced or eliminated, and thus effectively stiffen said column so that greater vertical load may be applied to the relatively slender column without exceeding permissible buckling stresses therein. Various additional changes of this nature will become apparent to those skilled in the art from the foregoing specification, and all such modifications and

changes falling within the scope of the appended claims are intended to be included therein.

I claim:

1. A support column for an off shore structure, said column comprising:

a submerged base portion, said base portion having an overall specific gravity exceeding that of the surrounding water;

an intermediate portion above said base portion, said intermediate portion being submerged and under tension and having an overall specific gravity less than that of said submerged base portion; and

an upper portion above said intermediate portion, said upper portion being at least partially submerged and buoyant and having an overall specific gravity less than that of said intermediate portion;

said lower portion exerting a downwardly directed, ballasting force on the base of said intermediate portion sufficient to hold said column in contact with submerged surface means underlying said base portion and said upper buoyant portion exerting an upwardly directed, lifting force on the top of said intermediate portion sufficient to maintain said intermediate portion in tension.

2. A support column as described in claim 1 wherein said column is defined by a plurality of similar cylindrical column sections of substantially the same diameter, said column sections being detachably connected together.

3. A support column as described in claim 1 wherein said upper column portion comprises a closed, generally cylindrical chamber and wherein said intermediate column portion comprises an open framework.

4. A support column as described in claim 1 wherein the interior of said intermediate column portion is in fluid communication with a surrounding body of water whereby said water may exert a buoyant force on said upper column portion.

5. A platform erected at an offshore work site comprising:

a substantially rigid column extending vertically from the submerged land underlying a body of water to above the surface of said water,

a plurality of chambers formed in said column and disposed axially along the length thereof,

at least one of said chambers forming a first compartment in said column adjacent the lower end thereof,

a material of density greater than water in said first compartment in an amount sufficient to hold the bottom of said column in contact with said submerged land,

at least one of said chamers forming a second compartment in said column vertically above said first compartment,

water filling said second compartment,

at least one of said chambers forming a third compartment in said column vertically above said second compartment,

at least a portion of said third compartment containing air in an amount to provide a positive buoyancy at the top portion of said column,

a work platform supported on the top portion of said column and above said surface of said water,

and means to regulate the amount of material in said first compartment and the amount of air in said third compartment with relation to each other to maintain the central portion of said column in tension.

6. A platform erected at an offshore work site comprising:

a substantially rigid cylindrical column of substantially uniform diameter extending vertically from the submerged land underlying a body of water to above the surface of said water,

a plurality of chambers formed in said column and disposed axially along the length thereof,

at least one of said chambers forming a first compartment in said column adjacent the lower end thereof,

a material of density greater than water in the said first compartment in an amount to hold the bottom of said column in contact with said submerged land,

at least one of said chambers forming a second compartment in said column vertically above said first compartment,

water filling said second compartment,

at least one of said chambers forming a third compartment in said column vertically above said second compartment,

at least a portion of said third compartment containing air in an amount to provide a positive buoyancy at the top portion of said column,

a work platform supported on the top portion of said column and above said surface of said water,

and means to regulate the amount of material in said first compartment and the amount of air in said third compartment with relation to each other to maintain the central portion of said column in tension.

7. A support column for an offshore work platform comprising:

an elongated column formed of a plurality of similar column sections detachably connected together in series relationship and set vertically in a body of water,

said column sections each forming a discrete compartment in said column,

a material of density greater than water in the column sections at the lowermost portion of said column in an amount sufficient to hold the bottom of said column in contact with the submerged land underlying said body of water,

the column sections in the longitudinally central portion of said column containing water in an amount to effect substantially neutral buoyancy throughout the said central portion of said column,

the column sections at the uppermost portion of said column containing air in an amount to effect positive buoyancy at the said uppermost portion of said column and to create tension throughout the said central portion of said column,

means to remove said material from the said column sections at the said lowermost portion of said column,

means to introduce air into said column sections at the said lowermost portion of said column to float said column on the surface of said water in a horizontal position,

means to attach and remove column sections to said column while said column is floating on the said surface of the water to alter the length of said column to accommodate a water depth at another offshore location.

8. A support column for an offshore work platform comprising:

an elongated cylindrical column of substantially uniform diameter formed of a plurality of similar column sections detachably connected together in series relationship and set vertically in a body of water,

said column sections each forming a discrete compartment in said column,

a material of density greater than water in the column sections at the lowermost portion of said column in an amount to hold the bottom of said column in contact with the submerged land underlying said body of water,

the column sections in the longitudinally central portion of said column containing water in an amount to effect substantially neutral buoyancy throughout the said central portion of said column,

the column sections at the uppermost portion of said column containing air in an amount to effect positive buoyancy at the said uppermost portion of said col-

umn and to create tension throughout the said central portion of said column,

means to remove said material from the said column sections at the said lowermost portion of said column,

means to introduce air into said column sections at the said lowermost portion of said column to float said column on the surface of said water in a horizontal position,

means to attach and remove column sections to said column while said column is floating on the said surface of the water to alter the length of said column to accommodate a water depth at another offshore location.

References Cited by the Examiner

UNITED STATES PATENTS

1,868,494	7/32	Collins	61—46
2,661,600	12/53	Hopkins	61—46.5
2,857,744	10/58	Swiger et al.	61—46.5
3,092,852	6/63	Devereux	114—.5

FOREIGN PATENTS

545,046	6/56	Italy.

EARL J. WITMER, *Primary Examiner.*

JACOB SHAPIRO, *Examiner.*