

June 7, 1960

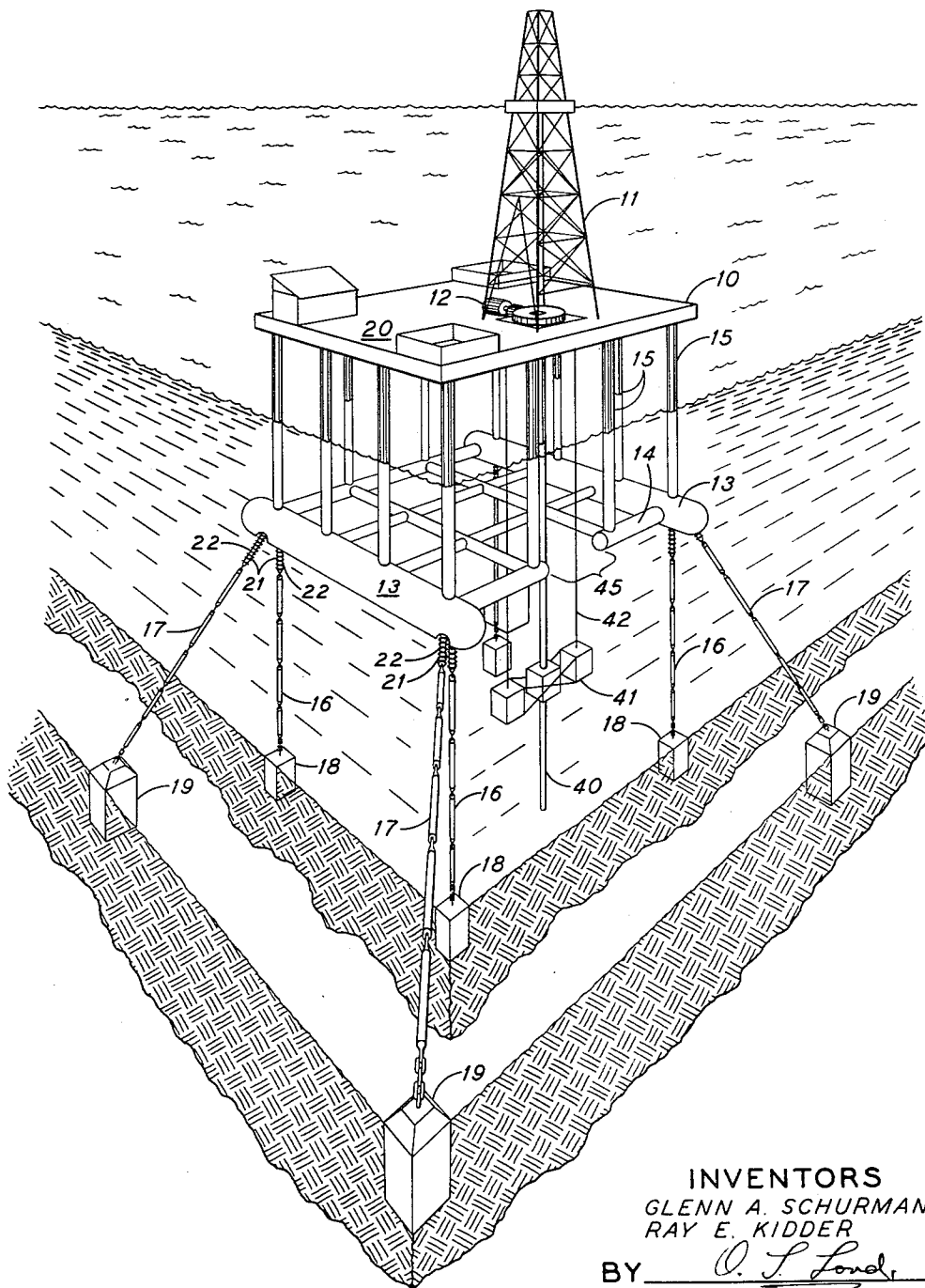
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2,939,291

ANCHORING SYSTEM FOR FLOATING DRILL STRUCTURE

Filed June 6, 1955

6 Sheets-Sheet 1



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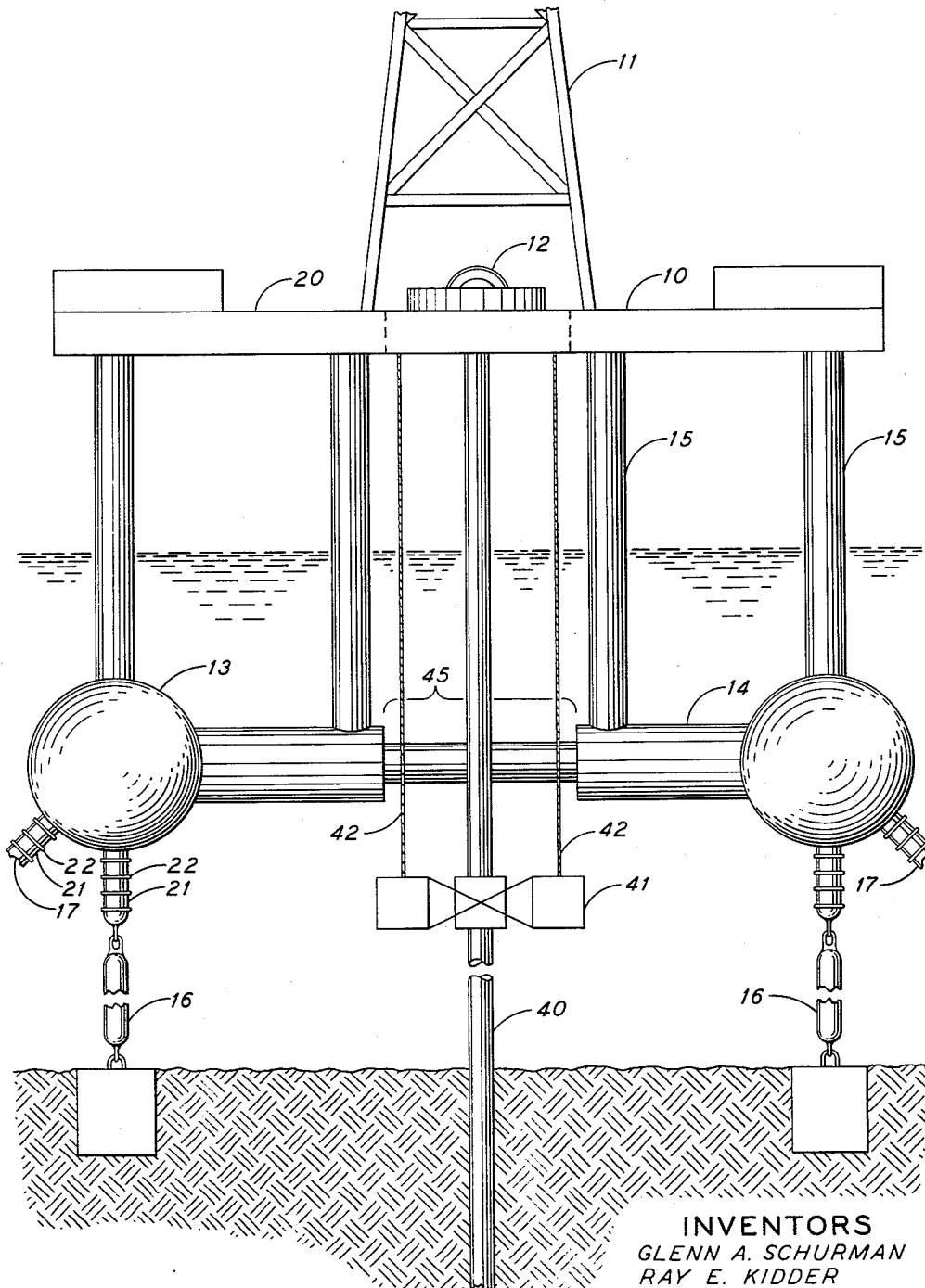


FIG. 2

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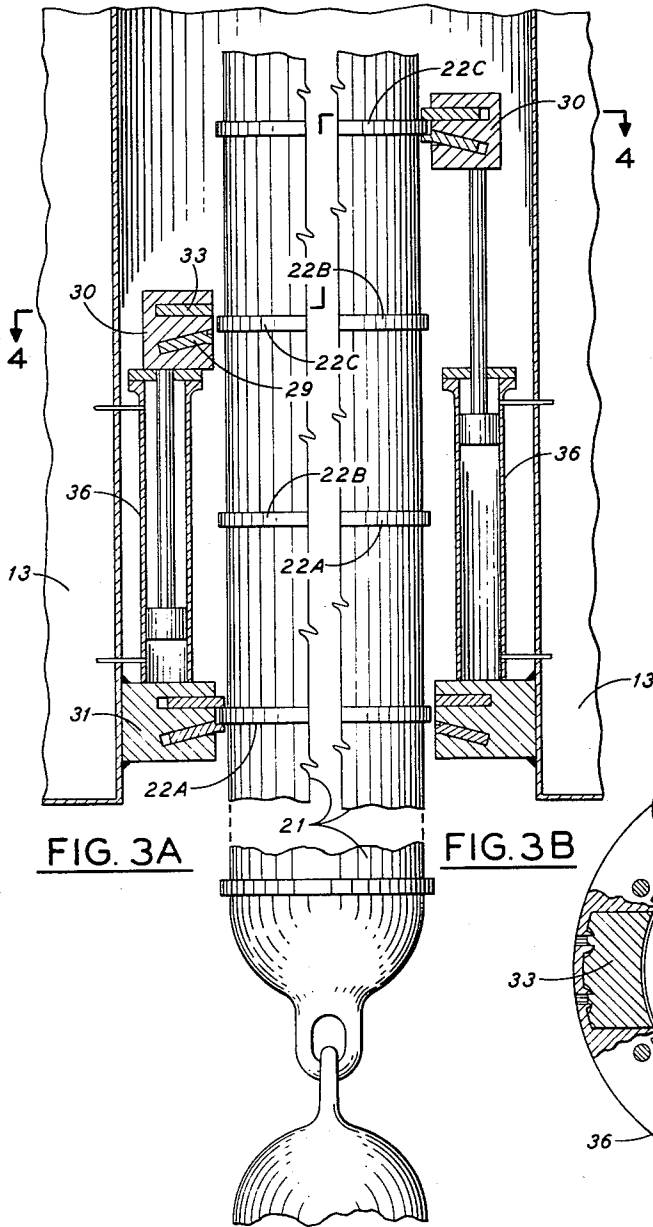


FIG. 3A

FIG. 3B

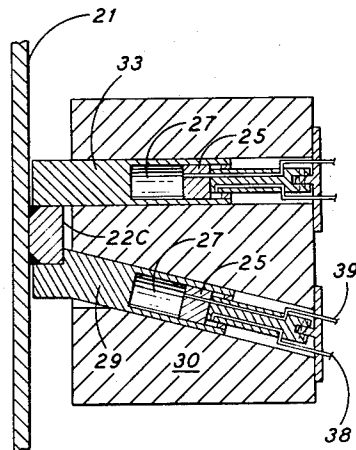


FIG. 5

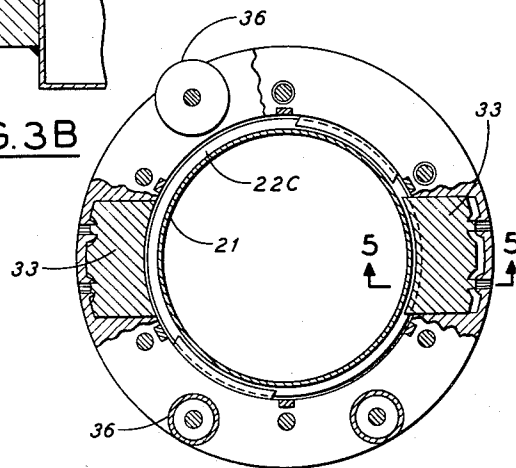


FIG. 4

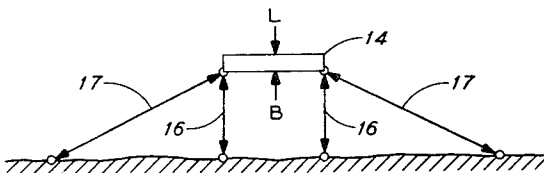


FIG. 11

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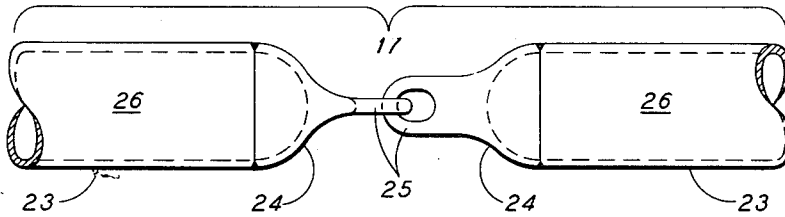


FIG. 6

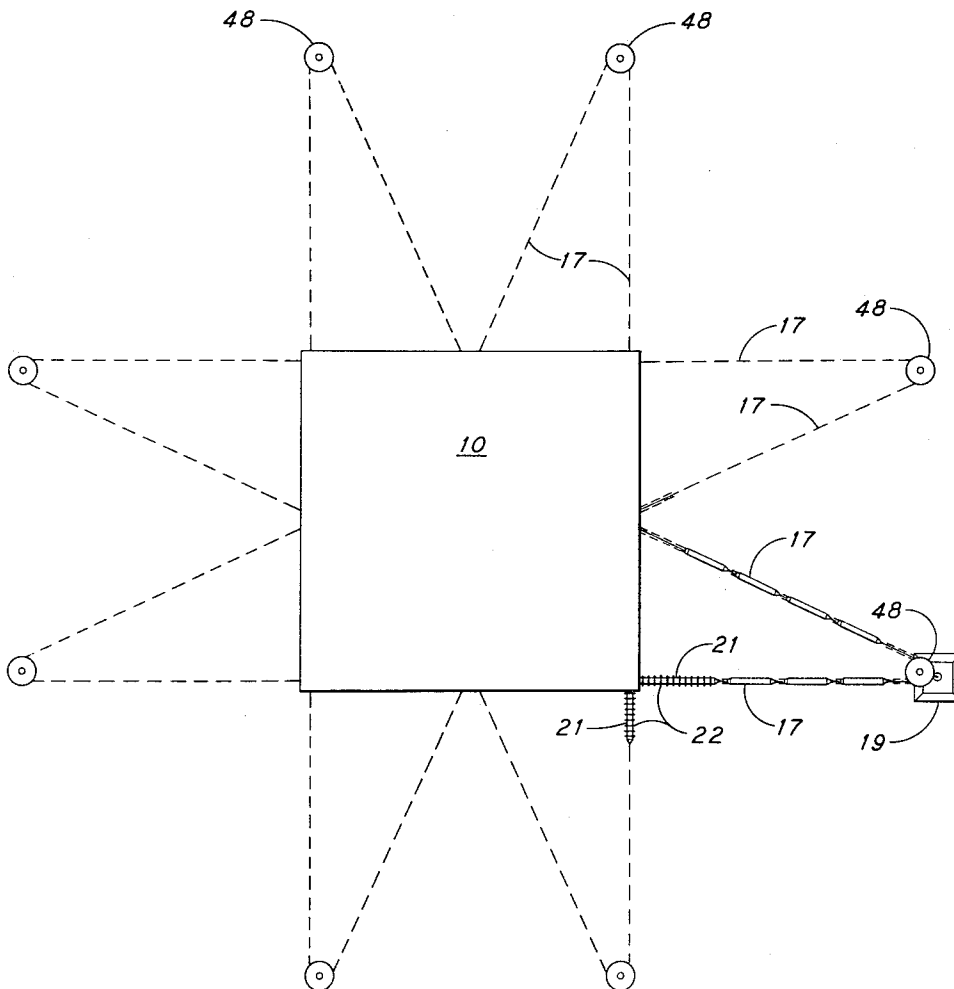


FIG. 7

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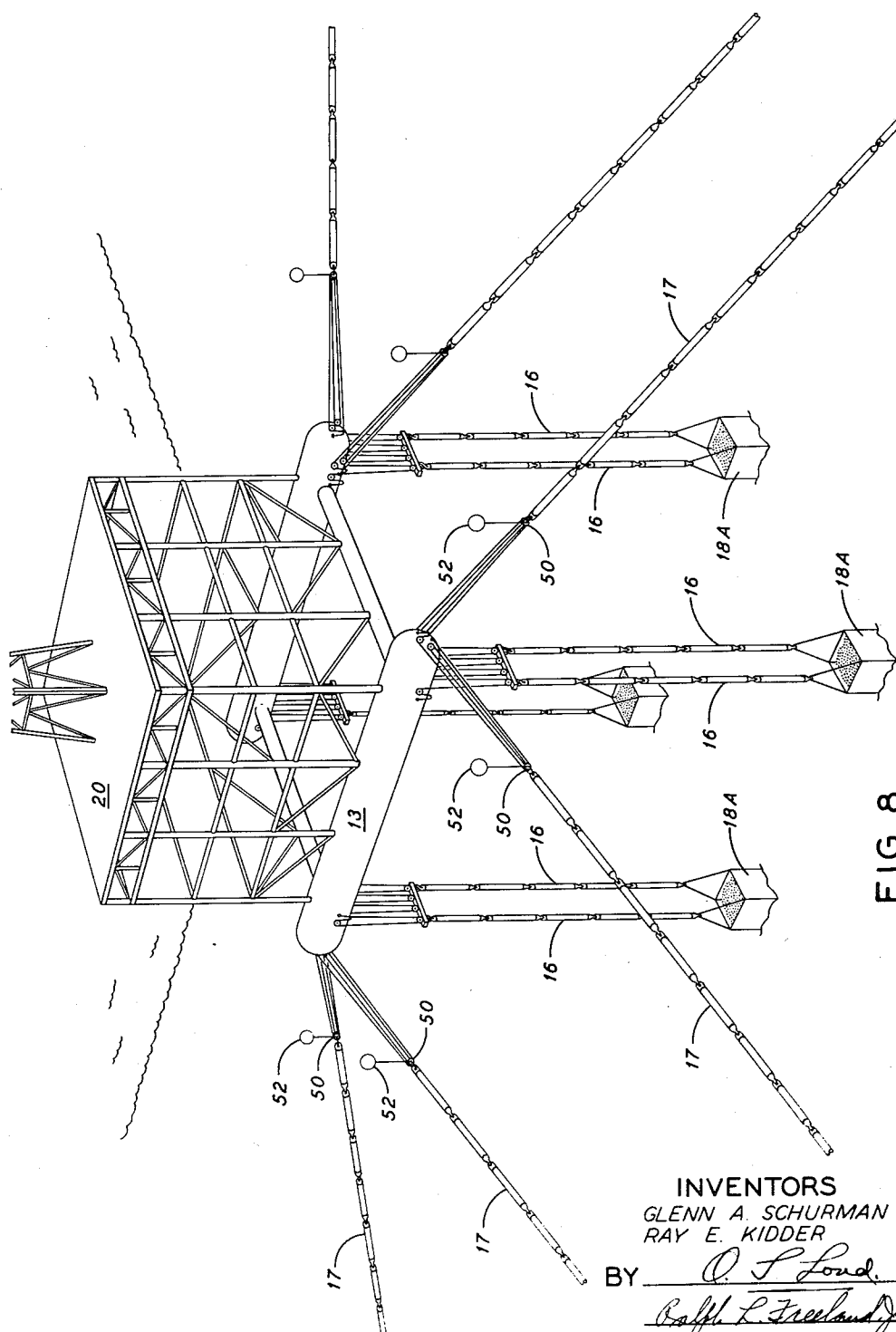
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6 Sheets-Sheet 5



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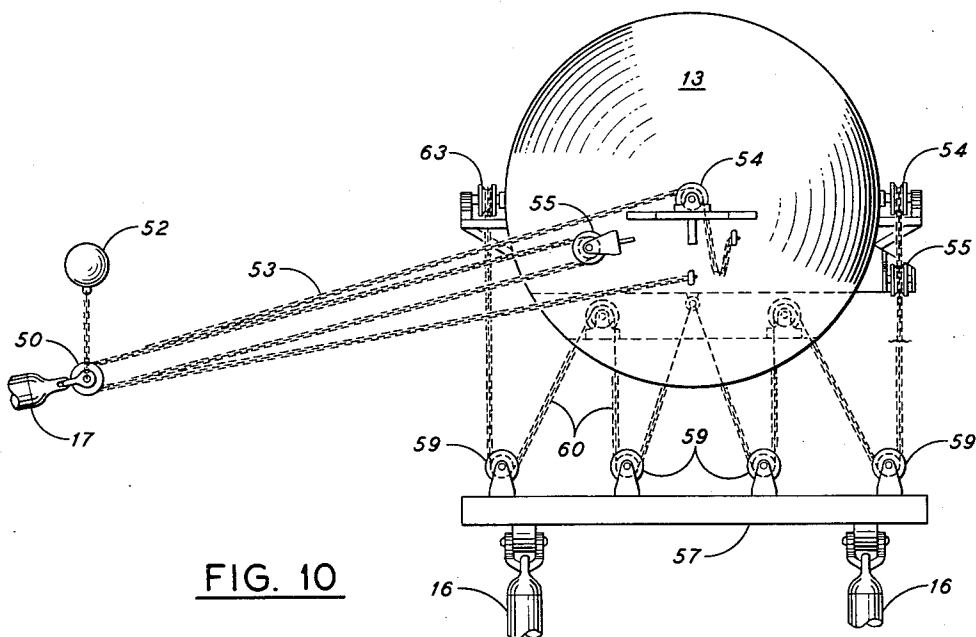


FIG. 10

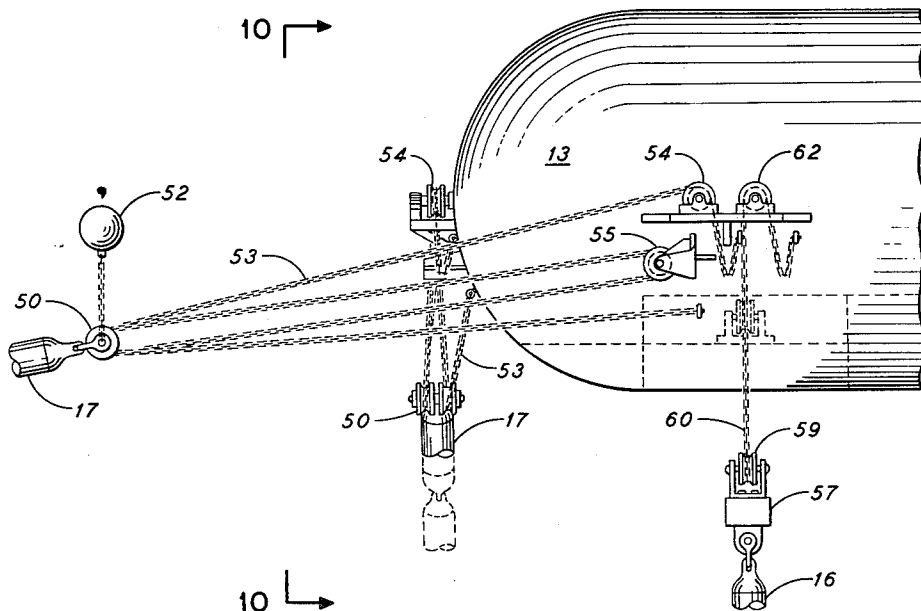


FIG. 9

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ANCHORING SYSTEM FOR FLOATING DRILL STRUCTURE

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Filed June 6, 1955, Ser. No. 513,298

1 Claim. (Cl. 61—46.5)

This invention relates to offshore drilling structures, more particularly to a method and apparatus for anchoring a floating structure from which drilling or producing operations may be performed, and has for an object the provision of an improved system for anchoring a floating structure against wind, wave and tide forces so that drilling operations may be performed in deep water, say 100 feet or more, by providing an anchoring arrangement wherein both the lateral and vertical anchor lines for the drilling structure have substantially neutral buoyancy, with said neutral buoyancy being distributed uniformly throughout the length of the anchor lines or chains, so that said lines may be maintained under positive tension to limit movements of said structure under load to those permitted by the elasticity of said lines.

In the drilling of wells at an underwater site, it has been proposed heretofore that such drilling, especially in relatively deep waters, from 100 feet upward, be performed from a substantially floating platform. The primary difficulties in actually drilling from a floating platform are those of maintaining the floating structure in a relatively rigid position under varying weight loads and maintaining the floating structure in a fixed position against the forces of waves, tide and wind. While the structure may be easily designed to support the weight of the derrick and several thousand feet of drill pipe required in the drilling of deep wells, the platform must be designed primarily to withstand lateral and rotational movements resulting from the effects of waves, wind and tide. While it has been proposed heretofore that anchoring lines, extending laterally from the drilling platform, be utilized to restrain the floating platform, previously known lateral anchoring systems have not provided adequate resistance to movement of the drilling platform under such effects to permit drilling therefrom with a firm connection between the underwater bottom and the platform, except for the usual conductor and drilling pipes. Accordingly, it has been considered more desirable to construct, where possible, platforms supported by steel framework supported directly on the ocean bottom. Obviously in water depth over about 100 feet, structural design of such platforms becomes extremely complex due to the large forces acting thereon as well as due to the major portion of the mass of the structure being supported at the end of a relatively limber structure. This type of construction is of course comparable to an inverted pendulum and accordingly quite susceptible to earthquake damage.

One of the reasons why previously known anchoring systems have not been capable of effectively withstanding the effects of wave, wind and tide forces is the manner in which conventional anchor lines dispose themselves even under great tension between the anchor and the floating structure. It is well known that such anchor lines normally assume the form of a catenary curve which has little horizontal restorative force even when large tensile forces are applied thereto. Anchor lines will take

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this catenary configuration in the water, whether such lines have either negative or positive buoyancy. Accordingly, previously known anchor lines have provided little more than loose moorings for a drilling structure, or working platform, against lateral or rotational forces.

In accordance with an important aspect of the present invention, there is provided a method of and apparatus for maintaining a floating structure substantially stable against large variations in the weight load on the drilling platform, while maintaining the floating structure in a relatively fixed position above the underwater drilling site, by providing anchoring lines wherein the strain thereon may be exactly balanced by a restoring force supplied by the elasticity of the lines. The entire load of the drilling platform and the drilling equipment may thus be supported by the buoyancy of the water while the floating structure is restrained against lateral and rotational movement due to the effect of waves, wind, and tide, through a plurality of laterally extending anchor lines which are of substantially uniform neutral buoyancy throughout their length. In a preferred form of the invention each individual element or segment of said anchor line is neutrally buoyant throughout its entire effective length. Further, in accordance with a preferred form of the invention, the displacing force is distributed to a plurality of anchor lines having uniform, neutral-buoyancy which surround the periphery of the floating drill platform by interconnection of at least a pair of said lines to individual underwater anchors to provide a restoration force opposing the displacement force around the floating structure, which is substantially independent of the direction of said displacement force arising from the effect of wind, wave or tide.

Further objects and advantages of the present invention will become apparent from the following detailed description taken 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 a preferred form of floating drill platform anchored in accordance with the present invention to provide a stable drilling structure above an underwater drilling site.

Fig. 2 is a side elevation view of the drilling platform shown in Fig. 1, illustrating in greater detail the method of securing anchor lines, embodying the present invention, to the floating structure.

Figs. 3A and 3B are cross-sectional views illustrating the securing and tensioning system for the anchor lines illustrated in the embodiment shown in Figs. 1 and 2, and illustrating respectively, the hydraulic operators in their retracted and extended positions.

Fig. 4 is a cross-sectional view taken in the direction of arrows 4—4 in Figs. 3A and 3B, with a portion being cut away through the retractable clamps to illustrate the construction thereof.

Fig. 5 is an elevational view through the operating shoes forming each clamp taken in the direction of arrows 5—5 in Fig. 4 and particularly illustrating the hydraulic operators for the clamp shoes.

Fig. 6 is an enlarged view of a portion of the uniformly distributed, neutrally buoyant anchor chains, constructed in accordance with the present invention, utilized for anchoring of the drill structure shown in Figs. 1 and 2 against lateral and rotational movement.

Fig. 7 is a schematic plan view of a method of distributing the lateral anchoring forces around the periphery of a floating structure.

Fig. 8 is a perspective view of an alternative anchoring system for the floating drill platform shown in Fig. 1, which particularly illustrates another method of secur-

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ing and positively tensioning the anchor lines for the drilling structure to a predeterminable extent.

Fig. 9 is a side elevation view of a portion of the anchor lines, and an enlarged view of one of the main buoyancy pontoons for the floating drill structure, particularly illustrating the positive tensioning system for the neutrally-buoyant anchor lines.

Fig. 10 is an end-elevation view of a portion of a main buoyancy pontoon, taken in the direction of arrows 10—10 in Fig. 9.

Fig. 11 is a stress diagram through a plane of symmetry of the anchoring system illustrating the stresses on the neutrally buoyant anchor lines forming the elements of the truss-like structure.

Referring now to the drawings, and in particular to Fig. 1, there is shown a preferred arrangement for a floating drill structure 10 which is adapted to support a derrick 11 and the associated drilling equipment, illustrated as 12, at an underwater drilling site, with the entire load of drilling equipment and housing facilities for personnel adapted to be supported by the buoyancy of the structure 10. The buoyancy of structure 10 is provided by a pair of enlarged buoyancy tanks 13 which, in the present embodiment, are integrally formed as a portion of the cell-like base structure 14. As shown, base 14 is constructed of hollow cylinders and forms the foundation for a plurality of vertical supporting columns 15.

In accordance with the present invention, the complete drill structure, including buoyant base 14, columns 15 and drill structure 10, is adapted to be floated to the drilling site, substantially fully assembled. After arrival at the drilling site, the floating drill structure is attached to a plurality of neutrally-buoyant vertical anchor chains 16 through which the entire structure is pulled downwardly into the water to a depth such that the entire structure is held considerably below its normal floating position in the body of water and without decrease in the buoyancy thereof. By this arrangement, there is applied to the vertical anchor chains 16 through the weight of underwater anchors 18 a positive tensile stress which is predeterminably controlled so that it is at all times greater than the load to be added to the deck of drilling structure 10. Thus, the only change in elevation of drilling platform 20, upon change in load, will be due to the decreased deformation, or elastic elongation, of the neutrally buoyant anchor chains 16, as the positive tension thereon is decreased. This deflection is equal, or nearly equal, to the change in height of a fixed platform under equal load variations.

While the anchoring system as thus far described prevents substantial change in the vertical position of the drilling structure in the body of water under normal changes in load during the drilling operation, if sufficient stability of the drilling structure is to be obtained to permit drilling therefrom the platform must be restrained against substantial lateral and rotational movement due to the effect of winds, waves and tides on the floating drill structure. As particularly discussed above, the anchors against lateral and rotational movement are constructed in accordance with the present invention to have substantially neutral buoyancy throughout their entire length. Thus, each line may be made to extend in substantially a straight line between its lateral anchor 19 and its joint-like connection to the floating structure 10. In the present embodiment, these connections are shown to be through the enlarged pontoon members 13. By the provision of said neutral buoyancy throughout the length of anchor line 17, the straight line relationship between the lateral anchors and the floating structure may be attained, since the chain at any given point will neither be more buoyant than the water nor less buoyant; hence, the catenary form normally assumed by an anchor line is particularly avoided.

By virtue of the neutrally buoyant anchor lines, there may be applied an effective positive tension to lateral

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anchor lines 17, which will resist displacement of platform 10 when variations in force, either lateral or rotational, are applied to the drilling structure, through wave, wind, or tide action. Thus, said force variations on the drilling structure may be made to act only to reduce or increase the positive tension in the snugged lateral anchor lines 17. In this manner, only relatively minor movements in the drilling structure will be experienced during drilling. In actuality, these movements will be less than those of an equivalent fixed tower because the lateral anchor lines are in effect members of a truss and the rigidity is greater than that of a slim tall tower. As shown in Fig. 11, each neutrally buoyant vertical and diagonal anchor line, while under tension, may be considered to be a jointed element or bar in a truss. While said truss includes a third dimension, the loading may be considered symmetrical about the plane of the simple truss comprised by lines 16 and 17, the ocean bottom and buoyancy member 14. The tension and compression forces are as illustrated by the arrowheads and the loads thereon represented as the variable work load L and the buoyant force B acting on base 14.

As particularly illustrated, floating drill structure 10 is preferably of sufficient height, as controlled by the length of vertical members 15, so that the upper deck 20 is from 30 to 50 feet above the mean surface level of the body of water, while the buoyancy tank or chamber structure 14 is desirably from 30 to 60 feet below the surface of the water. By this elevation of deck 20 and submergence of base 14, a small cross-sectional area is presented by the structure in those depths of water where wave and tide actions are most pronounced. Vertical columns 15 are likewise desirably made circular in cross-section so that they present little resistance to water flow therethrough.

In accordance with the present invention, as described above, neutrally-buoyant, lateral anchoring lines 17 are so constructed that they extend in substantially straight lines between lateral anchors 19 and their connections to the floating structure 10 through pontoons 13. The preferred structure of the lateral anchoring lines 17 is particularly illustrated in Fig. 6. As there shown, each line is provided with uniformly distributed buoyancy, by forming each section or length of line 17 from an elongated column, or pipe, 23, having its opposite ends closed by domelike link connectors 24 which are welded to the ends of pipes 23. The mating ends of connectors 24 may be formed as links of a chain, as indicated at 25. By this manner of construction, the buoyancy of the lateral anchoring chains 17 is distributed substantially throughout the length of the individual segments, with the walls of pipes 23 and the weight of end members 24 being proportioned to the volume of enclosed space 26 within each segment. The entire anchor line may thus be made neutrally buoyant throughout its entire length. Alternatively, of course, the entire chain or anchor 17 may be formed as a single elongated section of pipe with internal bulkheads at reasonable distances to increase strength and improve safety. As shown, each line extends from a lateral anchor 19 to a takeup mechanism, such as that illustrated in Figs. 1 and 2, which include rings 22. The manner of utilizing rings 22 to positively tension lines 17 will be described hereinafter. Such a single elongated section of pipe will, of course, be proportioned throughout its length to have a uniformly distributed buoyancy and the weight component thereof will be such that the entire line will be neutrally buoyant in sea water. Thus, the desired straight line relationship of lines 17 is maintained throughout its length.

With particular reference to the method of controlling the positive tension in both vertical anchor lines 16 and lateral anchor lines 17 there is illustrated in Fig. 2 an enlarged view of the upper end of both of these anchor lines. As shown there, both lines terminate in a cylindrical section identified generally as 21, each of which

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is provided with a plurality of longitudinally spaced ring members 22 surrounding the cylindrical elements 21. As further shown in Fig. 2, these cylindrical elements 21 and their rings 22 form the take-up of positive tensioning means in conjunction with the jacking arrangement particularly illustrated in Figs. 3A, 3B, 4 and 5. As best seen in these figures, ring members 22 are adapted to be engaged by a plurality of upper and lower clamping shoes 29 and 33, forming an upper clamp means 30 and a lower clamp means 31, which circumferentially surround column 21. As best seen in Figs. 4 and 5, both the upper and lower clamping means 30 and 31 are constructed of a plurality of shoe segments 29 and 33 which may be laterally extended, as shown in Fig. 5, or retracted to the position shown by the lower clamping means in Fig. 3B, and the upper clamping means in Fig. 3A. These shoe segments are adapted to be extended and retracted in response to the hydraulic cylinder and piston arrangement, specifically illustrated in Fig. 5, including piston elements 25, which remains substantially stationary while the cylinder means 27, formed within the shoe segments 29 and 33, moves relative to pistons 25 under the influence of hydraulic pressure supplied by lines 38 and 39.

In operation, each of the shoe segments 29 and 33 forming one of the clamping means is extended into engagement with one of the ring members 22 to secure column 21 to platform 10 through pontoon 13, a portion of which is shown in Figs. 3A and 3B. With the lower clamp 31 in engagement with one of the rings 22A, as seen in Fig. 3A, the upper clamping means 30, including shoe segments 29 and 33, are brought into engagement with an upper clamping ring 22C. Lower clamping means 31 is then released and the pontoon 13 drawn downwardly along column 21 by lifting or pushing of the upper clamping means 30 against ring 22C, through operation of the hydraulic ram means 36, to the position illustrated in Fig. 3B. By alternate extension and retraction of the shoe segments and operation of the hydraulic rams 36, pontoon 13 is drawn downwardly along column 21 and there is applied thereto and the interconnecting anchor lines 16 and 17 the desired positive tension. For a further description of the hydraulic jacking arrangement described hereinabove, reference is made to the copending application of Celestine Paul Besse, Serial No. 430,925, filed May 19, 1954 and now abandoned, which application is assigned to the assignee of the present invention.

Further in accordance with the present invention, the lateral restoring forces for the drilling structure may be peripherally distributed by interconnecting a plurality of the lateral anchoring lines 17 in the manner shown in Fig. 7. As there seen, at least two of the individual, neutrally buoyant lateral anchor lines 17 may be interconnected to each other through a sheave system, including sheaves 48 located underwater at the lateral bottom anchors 19. The advantage of the arrangement of Fig. 7 is that, irrespective of the direction of the lateral displacing forces applied to the drilling structure 10, the restoring forces on each of the neutrally buoyant anchor lines 17 is better distributed and the individual stress and elastic deformation of any one of the anchor lines is decreased to about one-half of the disturbing force on the anchoring line. Only one end of each pair of lines need be snugged in the manner described herein.

In the preferred manner of erecting the structure illustrated in Fig. 1, the drilling structure 10, as mentioned above, is floated to its drilling site after at least some of the anchors 18 and 19 have been installed in the underwater bottom. These anchors may be secured in the underwater bottom by boring, jetting, or the like. Alternatively, some of the anchors may be of proper mass and weight to provide the desired anchoring force, but yet be movable by auxiliary lifting and towing equipment. Some of the anchors, such as 18, may even be carried with the drilling structure by the addition of

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further buoyancy tanks to structure 10, before the arrival of the floating drilling platform, while others of the vertical anchors 18 may be installed at the desired drilling site.

Referring now to the alternative embodiment illustrated in Figs. 8, 9, and 10, there is shown a further method of tensioning the neutrally-buoyant vertical anchor lines 16 and lateral lines 17, after initial engagement is made between said lines and their anchors, such as those identified as 18A, and main buoyancy pontoon 13 for platform 10. As best seen in Figs. 9 and 10, each of the lateral anchor lines, whose anchors are not shown, terminates in a sheave assembly 50 which is buoyantly supported in the water by float 52. Through sheave assembly 50, the chains, such as 53, apply positive tension to lines 17 by a takeup motor (not shown) which by means of suitable gear reduction, applies torque to takeup sheave 54 and idler sheave 55, both positioned within pontoon 13, to draw chains 53 and lines 17 taut. Since pontoons 13 will have a diameter of several feet, the essential gearing and drive motors (not shown) may be suitably disposed and operated therein. Control of the tension applying means may be located either within the pontoon, or remotely operated from drilling deck 20.

Vertical anchor lines 16 are arranged to be similarly snugged, in the embodiment of Figs. 9 and 10, but as shown, these lines may include a pair of vertical chains which terminate in header 57. Header 57 supports a plurality of sheaves 59, through which takeup cable 60 is suitably threaded and then connected to tension applying drive mechanisms, such as takeup or drive sheaves 62 and 63. By use of a pair of takeup sheaves, horizontal stability, during the drawdown and tensioning operation on the vertical anchor lines 16, may be maintained with reduced tension on the individual tensioning lines.

As schematically represented in both Figs. 2 and 3, the well is drilled through conductor pipe 40, which returns drilling fluid to the elevated drilling deck 20. In relatively deep water, pipe 40 is desirably supported along its length by a stiffener arrangement 41. Device 41 desirably comprises a pair of buoyancy chambers supported from the bottom of the drilling deck 20 through cables 42. The opening, designated as 45, in the underwater buoyancy section 14 permits conductor pipe 40 to be terminated above the water, so that if petroleum production is obtained, it may be produced therefrom and yet permit the floating drill structure 10 to be refloated, free of the restraining anchor lines, and moved to a new drilling location.

Alternatively, the pipe stiffener 41 may have a density greater than water so that through suitable connections between the conductor pipe 40 and elements 41 there may be applied a suitable stabbing force on the conductor pipe. Such an arrangement is desirable under certain circumstances due to the relative buoyancy of even fairly large diameter conductor pipe in water. Thus, the initial "spudding in" of the well at the underwater drilling location may be aided by application of weight supplied by elements 41 to the conductor pipe.

From the foregoing description it will be seen that there is provided a method of erecting a floating drill structure in a relatively deep body of water wherein the drilling platform is confined to a smaller amount of movement than is possible with a tower of equal height erected on the ocean bottom. The elastic deformation of our neutrality buoyant anchor lines, when formed of steel, amounts to a few thousandths of an inch per linear foot of the anchor lines, so that each anchor line is held continuously under positive tension. Through use of said uniformly distributed neutrally-buoyant anchor lines, each anchor line extends from the floating structure to the respective anchors in substantially a straight line and exerts a restoration force that is at all times equal to the tension imposed thereon by waves, wind, and tide, acting on the floating structure.

Various other modifications and changes in the method of erecting a stabilized floating drill structure on a body of water will occur to those skilled in the art. Likewise variations in the manner of constructing the neutrally-buoyant anchor lines to hold said floating structure against displacement under external forces will become apparent from the foregoing description. However, all such modifications or changes in the method of establishing the floating structure and its constraint against movement which fall within the scope of the appended claim are intended to be included therein.

We claim:

A floating structure for supporting a work platform above a deep water work site which comprises a buoyant base member including at least a pair of elongated cylindrical buoyancy chambers, cylindrical cross members joining together said pair of elongated cylindrical buoyancy members in spaced, parallel relationship to form an open network buoyancy platform, a plurality of columns extending vertically above said buoyancy platform, a work platform supported on said columns, the buoyancy of said buoyant platform being substantially in excess of the total weight of said work platform and the working weight to be applied to said platform, a plurality of vertical anchor lines each comprising a plurality of hinged interconnected closed pipe sections of substantially neutral buoyancy extending vertically downward from said buoyancy platform and adapted to engage a similar plurality of anchor means embedded in the underwater bottom, positive tension means connecting said buoyancy platform and said vertical anchor lines for pulling said buoyancy platform along the length of said vertical anchor lines to hold said buoyancy platform at an elevation below the normal wave and tide action, a plurality of lateral anchor lines each comprising a plurality

of hinged interconnected closed elongated tubular segments of substantially neutral buoyancy extending from said buoyancy platform outwardly to anchor means at the underwater bottom and disposed with the individual segments forming said lines extending in substantially a straight line relationship through their length from said anchor means to said buoyancy platform, means interconnecting at least two of said lateral anchor lines, said interconnecting means including flexible force transmitting means connecting the outwardly disposed ends of two lateral anchor lines and pulley means positioned on said anchor means, which pulley means said force transmitting connecting means operably engages to transmit forces applied to and reactive forces generated within one of said two connected lateral lines to the other of said interconnected lateral lines, and means for applying a predeterminable tension to said lateral anchor lines to restrain said work platform from lateral movement, said tension applying means comprising connecting means between said buoyancy platform and at least one of said interconnected lateral anchor lines, including means for applying a predetermined tensile force to said lateral lines and means for maintaining said applied force.

References Cited in the file of this patent

UNITED STATES PATENTS

27,571	Schofield	Mar. 20, 1860
2,399,656	Armstrong	May 7, 1946
2,476,309	Lang	July 19, 1949
2,772,539	Sandberg	Dec. 4, 1956
2,777,669	Willis et al.	Jan. 15, 1957
2,791,979	Willis	May 14, 1957

FOREIGN PATENTS

649	Great Britain	1890
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