

[54] **MOORING SYSTEM FOR FLOATING STRUCTURES**[75] Inventor: **Everald V. Wright**, Pittsburgh, Pa.[73] Assignee: **Dravo Corporation**, Pittsburgh, Pa.[22] Filed: **Sept. 4, 1973**[21] Appl. No.: **394,200**[52] U.S. Cl. **114/230**, 9/8 P, 61/46, 114/5 F[51] Int. Cl. **B63b 21/00**

[58] Field of Search 9/8 P; 114/230, 43 S, .5 D, 114/5 F, 206 R; 61/46, 48, 50, 46.5

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Primary Examiner—Trygve M. Blix*Assistant Examiner*—Galen L. Barefoot*Attorney, Agent, or Firm*—Parmelee, Miller, Welsh & Kratz[57] **ABSTRACT**

A mooring system is disclosed for securing floating structures to the bottom of a body of water. A base unit having a tapered recess or protrusion in the top surface is fixed to the bottom. A mooring unit sized and shaped to fit the tapered recess or protrusion in the base unit is movably attached to the floating structure so as to allow relative vertical movement between the mooring unit and the floating structure. The mooring unit is secured to the base unit so that the floating structure is horizontally restrained but can move vertically in response to waves or tidal action.

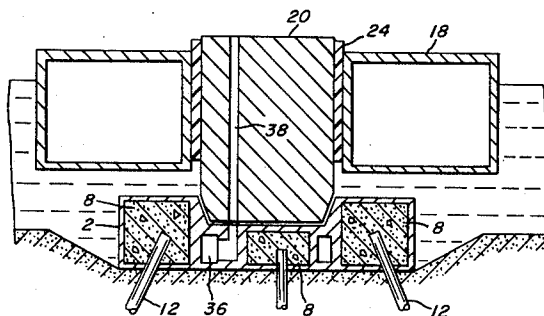
5 Claims, 7 Drawing Figures

FIG. 1.

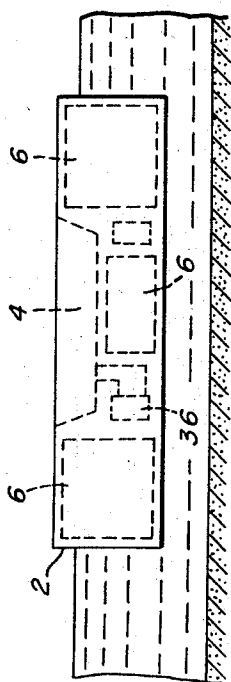


FIG. 2.

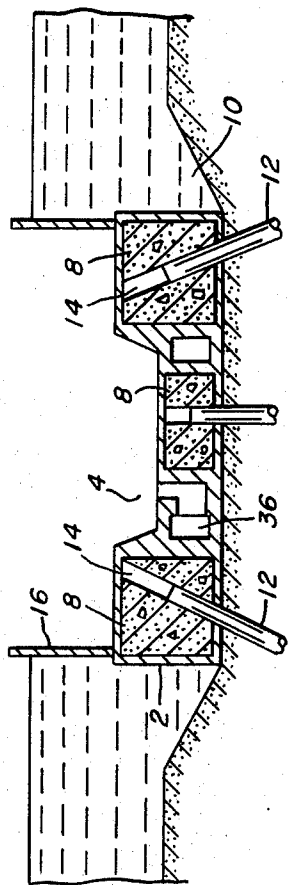


FIG. 3.

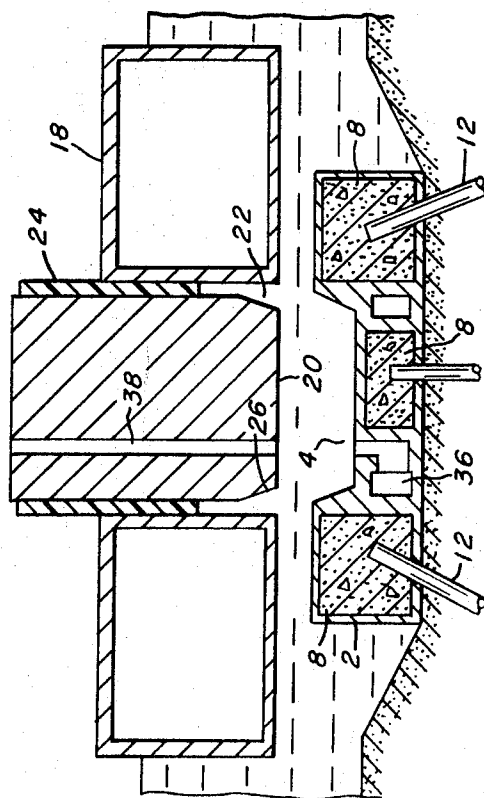


FIG. 4.

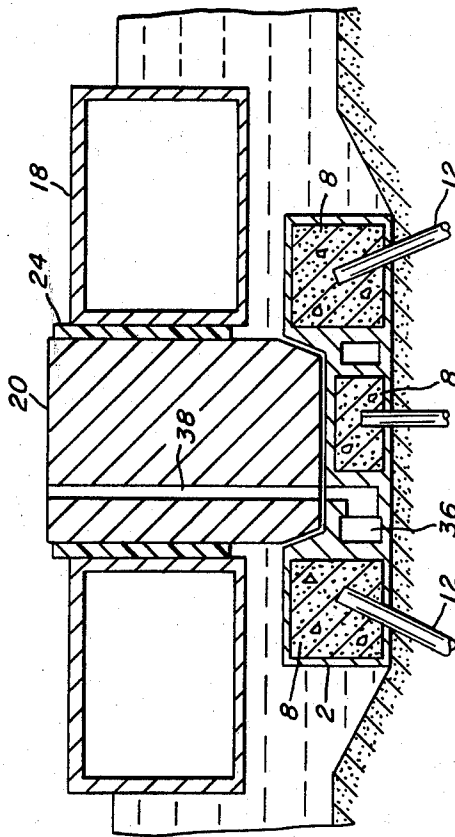


FIG. 6.

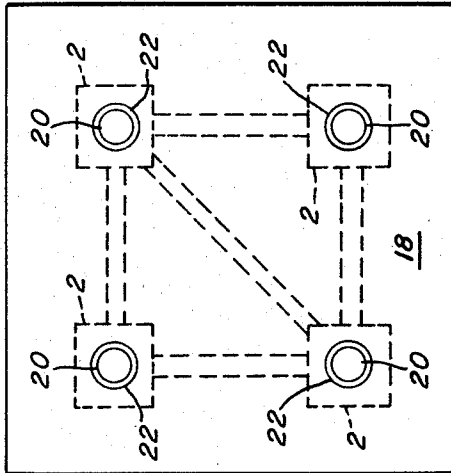


FIG. 7.

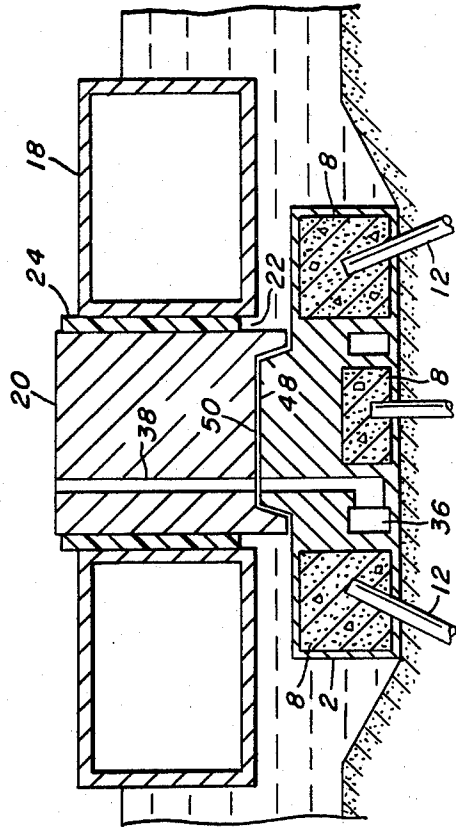
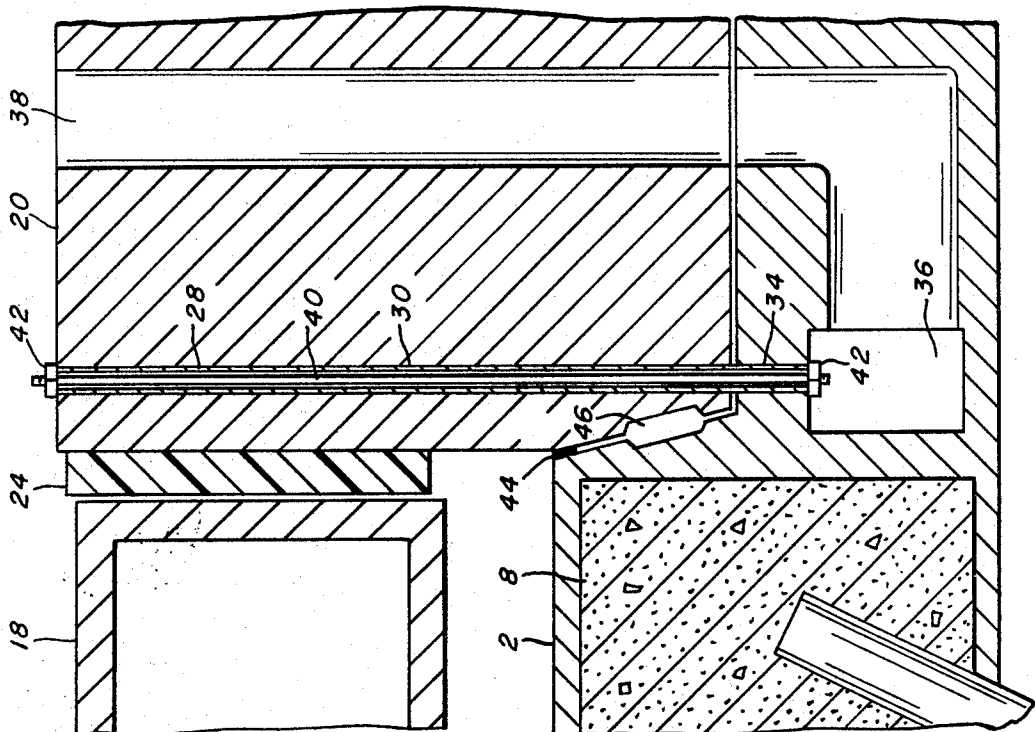


FIG. 5.



MOORING SYSTEM FOR FLOATING STRUCTURES

BACKGROUND OF THE INVENTION

There is a developing need to permanently moor floating structures in bodies of water. Such structures as power plants, airport segments, breakwaters, harbors, storage platforms and other floating platforms are presently being conceived for siting in rivers, lakes, estuaries, oceans, or prepared basins in communication with these water bodies. Such structures would be remotely fabricated and floated to the site of their permanent mooring.

Existing moorings presently utilize various combinations of three basic methods for resisting the wind and water forces involved:

a. by "spuds" or caissons lowered to and sometimes driven into the bottom through the body of the structure;

b. by mooring lines attached either to adjacent structures above water or to anchors in the sea floor;

c. by surrounding the floating structure with a series of fixed structures, and resisting the lateral forces by direct contact through energy absorbing devices.

When considering the permanent mooring of such large floating structures, lateral forces due to tornadoes, hurricanes, and waves become so large that it is impractical to attempt to resist such forces by the use of the normal mooring methods. This impracticality is due to the required multiplicity of units in the case of spuds and mooring lines, or to the substantial structures necessary to surround the unit in the third case. Erecting a mooring on site after moving a structure to position results in unacceptable exposure time before the mooring is capable of any substantial resistance to the natural forces. In addition, the magnitude and cost of surrounding structures is great.

In general, the existing mooring designs are highly site-dependent based on the foundation conditions at the site. Varying foundation conditions require completely different concepts of mooring, therefore affecting the design of the structures to be moored.

The mooring system herein described is capable of resisting the high lateral forces described above while also providing rapid site installation and development of reasonable lateral resistance very soon after the floating structure arrives at the mooring site. The components of the system are amenable to considerable off-site fabrication and incorporate available materials. The system provides for simple installation of the floating structure at the site. Materials are used in such a manner as to effectively resist deterioration, even in a corrosive ocean environment, and provide for inspection and replacement of those components subject to wear and deterioration if such does occur after a period of time.

Also of importance is the fact that various components for the system may be fabricated at different places and will fit together positively at the time of siting. It is practical with the described system to visually inspect the important components in a dry condition at various stages of installation to assure quality.

SUMMARY OF THE INVENTION

In the present invention, a buoyant base unit is constructed which has a matable portion, such as a tapered recess or protrusion, in the top surface. The base unit

is floated to the desired site and is then rendered non-buoyant by the addition of ballast. When positioned in the proper location on the bottom of the body of water, it is fixed to the bottom, either by the use of piling passed through the base unit and into the bottom, or simply by the weight and friction of the ballasted unit. A mooring unit is movably attached to a floating structure at the time of assembly in such a way as to allow relative vertical movement between the mooring unit and the floating structure. The mooring unit has a lower surface sized and shaped to fit the matable portion in the base unit. After the floating structure is assembled and located at the desired site, the mooring unit is lowered into the tapered recess or over the tapered protrusion in the base unit and is permanently secured to the base unit. The floating structure is thus restrained from lateral movement but can move vertically in response to waves or tidal pressure.

Various embodiments of this system allow its use with many different foundation conditions thereby allowing the moored structures to be of standard design.

The high force resisting capability of individual mooring units of the proposed type reduces the requirement of multiple units to a very low number. Off-site fabrication of large portions of the mooring structure in a shore-based manufacturing yard contributes to economy through more predictable cost and scheduling, particularly in the case of off-shore ocean sites.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevation view of the buoyant base unit of the present invention as it is floated to the mooring site;

FIG. 2 is a sectional view of one embodiment of the base unit of the present invention having a cofferdam, showing the ballast and piling used to fix the base unit to the bottom;

FIG. 3 is a sectional view of the mooring system of the present invention showing the floating structure positioned at the desired site prior to the securing of the mooring unit to the base unit;

FIG. 4 is a sectional view of the mooring system of the present invention when secured;

FIG. 5 is a sectional view of a portion of the mooring system of the present invention showing a means for securing the mooring unit to the base unit;

FIG. 6 is a plan view of a floating structure moored by four of the mooring systems of the present invention showing the structural relationship of the base units; and

FIG. 7 is a view similar to FIG. 4 showing an alternate embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention can best be understood by reference to the accompanying drawings which are schematic in nature and which generally show the elements of the present invention. In FIG. 1, a buoyant base unit 2 having a matable portion such as a tapered recess 4 in the top surface thereof, is floated to the desired mooring site. Chambers 6 are provided in the base unit 2 for the introduction of ballast to render the base unit 2 non-buoyant upon reaching the desired site. Upon arrival at the final mooring site, the base unit 2 is submerged by the introduction of ballast 8, such as concrete, water, or other suitable substance, into the

chambers 6 as shown in FIG. 2. The base unit 2 may be placed directly on the bottom of the body of water, or, if necessary, may be placed in an excavation 10 prepared in the bottom, to make a suitable resting place for the base unit 2. If, in a particular application, the ballast 8 is not sufficient to fix the base unit 2 to the bottom by weight and friction, pilings 12 may be used to pin the base unit 2 to the bottom. The pilings 12 are driven through pre-formed sleeves 14 in the base unit 2 and made integral with the base unit 2 by poured in place concrete. In one embodiment of the present invention, a removable cofferdam 16 is attached to the base unit 2 so that the piling 12 can be driven through the base unit 2 and concreted in a dewatered condition for better quality control.

As shown in FIG. 3, the floating structure 18 is located at the desired site above the fixed base unit 2. The floating structure 18 is generally shown in the drawings and may be any large remotely fabricated structure such as a section of a power plant, airport, breakwater, harbor, storage platform or other floating platform. Such a floating structure 18 would often require a plurality of the mooring systems of the present invention, but for the purposes of this description only one such system is shown.

During assembly of the floating structure 18, a mooring unit 20 is assembled within a vertical channel 22 in the floating structure 18. The mooring unit 20 is movably attached to the floating structure 18 in such a way as to allow relative vertical movement between the mooring unit 20 and the floating structure 18. Energy absorbing fenders 24 may be provided around the outer perimeter of the mooring unit 20 between the floating structure 18 and the mooring unit 20 to provide for limited relative lateral movement and energy absorption. These energy absorbing fenders 24 are so attached as to be removable if they become worn, and may have plates, teflon, or some other friction-reducing surface bonded thereto so that friction is reduced and the floating structure 18 can move up and down as water level varies without inducing excessive vertical forces to the mooring unit 20. The mooring unit 20 has a matable portion, such as a tapered bottom 26 sized and shaped to match the tapered recess 4 in the top of the base unit 2. In another embodiment shown in FIG. 7, the base unit would have a tapered protrusion 48 on the top surface, and the mooring unit would then have a tapered recess 50 sized and shaped to fit the protrusion 48 in the base unit. When assembled in the vertical channel 22 of the floating structure 18, the mooring unit 20 is supported within the floating structure 18 so that the bottom 26 of the mooring unit 20 would lie in a plate similar to the bottom of the floating structure 18. Upon arrival at the final mooring site, the floating structure 18 is positioned directly above the previously positioned base unit 2 by temporary mooring during periods of relatively calm sea and wind conditions. The mooring unit 20 is then lowered to engage the tapered recess 4 in the base unit 2 as shown in FIG. 4. At this time, due to the weight of the mooring unit 20, and the tapered fit between the mooring unit 20 and the base unit 2, adequate mooring resistance would be developed to resist normal weather conditions. The interior of the mooring unit may, in certain embodiments, be filled with concrete to provide additional weight and overturning resistance. If necessary, the excavation 10 would be made so that the top surface of the base

would be below the maximum depth which the floating structure would reach under low water wave motion conditions.

As shown in FIG. 5, the mooring unit 20 preferably has protective tubes 28 inserted through vertical holes 30 formed in the mooring unit 20, and through similar holes 34 formed in the base unit 2. A cavity 36 formed in the base unit 2 provides dewatered access to the lower end of the tubes 28 located in the base unit 2. Access to the cavity 36 is through a vertical shaft 38 extending upward through the mooring unit 20 to above the water surface. Post-tensioning strands 40, such as cables or bars, are inserted through the tubes 28, and are held by anchorages 42 at the top of the mooring unit 20, and in the cavity 36 in the base unit 2. The post-tensioning strands 40, when stressed and anchored according to established procedures, effectively render the base unit 2 and the mooring unit 20 monolithic, and provide a high moment resisting capacity to the mooring unit 20 making it capable of resisting maximum imposed forces. The shaft 38 and cavity 36 provides access to the lower end of the post-tensioning strand 40 for proper installation of the anchorages 42 and for continual inspection of the anchorages 42 and strands 40 during the operational life of the floating structure.

In certain applications, a temporary seal 44 may be required between the mooring unit 20 and the base 2 so that the interior of the mooring unit 20 can be dewatered immediately after installation. The space 46 between the mooring unit 20 and the base unit 2 formed by matching channels in the mooring unit 20 and the base unit 2 can be filled with grout for water tightness and may have "keys" for shear transfer as is well known in the art.

FIG. 6 shows how multiple base units 2 may be tied together structurally to space the tapered recesses 4 at predetermined positions to form a complete mooring system. Multiple mooring units 20 would be suspended in channels 22 in the floating structure 18 at the same predetermined positions to allow a proper fit when joined to the base units 2.

I claim:

1. A mooring system for securing floating structures to the bottom of a body of water subject to waves or tidal action, comprising:

a base unit having a cavity therein and a tapered recess in the top surface thereof;

means for fixing the base unit to the bottom including ballast, sleeves formed in the base unit, and piling driven through the sleeves into the bottom;

a mooring unit with a shaft therein, located so as to provide access to the cavity in the base unit, and a lower surface having a tapered protrusion sized and shaped to fit the tapered recess in the base unit, said mooring unit being movably attached to the floating structure so as to allow relative vertical movement between the mooring unit and the floating structure;

means for securing the mooring unit to the base unit, whereby the floating structure is horizontally restrained, but can move vertically in response to waves or tidal action, which securing means includes tubes disposed within the base unit and the mooring unit, with post-tensioning strands passing through the tubes, and anchorages within the base unit cavity and above the mooring unit, whereby the post-tensioning strands are secured by the an-

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chorages of the base unit and the mooring unit; and means for sealing the second matable portion to the first matable portion so as to allow dry access through the shaft and cavity.

2. The mooring system as defined in claim 1 including a removable cofferdam attached to the base unit to allow for dewatered installation of the pilings.

3. The mooring system of claim 1 including energy absorbing fenders disposed at the locus of movable attachment of the mooring unit and the floating structure.

4. A mooring system for securing floating structures to the bottom of a body of water subject to waves or tidal action, comprising:

a base unit having a tapered recess in the top surface thereof;

ballast in the base unit to render the base unit non-buoyant;

piling fixing the base unit to the bottom;

a mooring unit having a lower surface sized and shaped to fit the tapered recess in the base unit, said mooring unit being movably attached to the floating structure so as to allow relative vertical movement between the mooring unit and the float-

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ing structure;

energy absorbing fenders disposed at the locus of movable attachment of the mooring unit and the floating structure;

means for securing the mooring unit to the base unit, whereby the floating structure is horizontally restrained, but can move vertically in response to waves or tidal action; and

the securing means comprises tubes disposed within the base unit and the mooring unit, with post-tensioning strands passing through the tubes, and anchorages within the base unit and above the mooring unit, whereby the post-tensioning strands are secured by the anchorages of the base unit and the mooring unit.

5. The mooring system as defined in claim 4 wherein the base unit has a cavity therein, the anchorages of the base unit being located in said cavity, and the mooring unit has a shaft therein, located so as to provide access to the cavity in the base unit, and including

means for sealing the second matable portion to the first matable portion so as to allow dry access through the shaft and cavity.

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