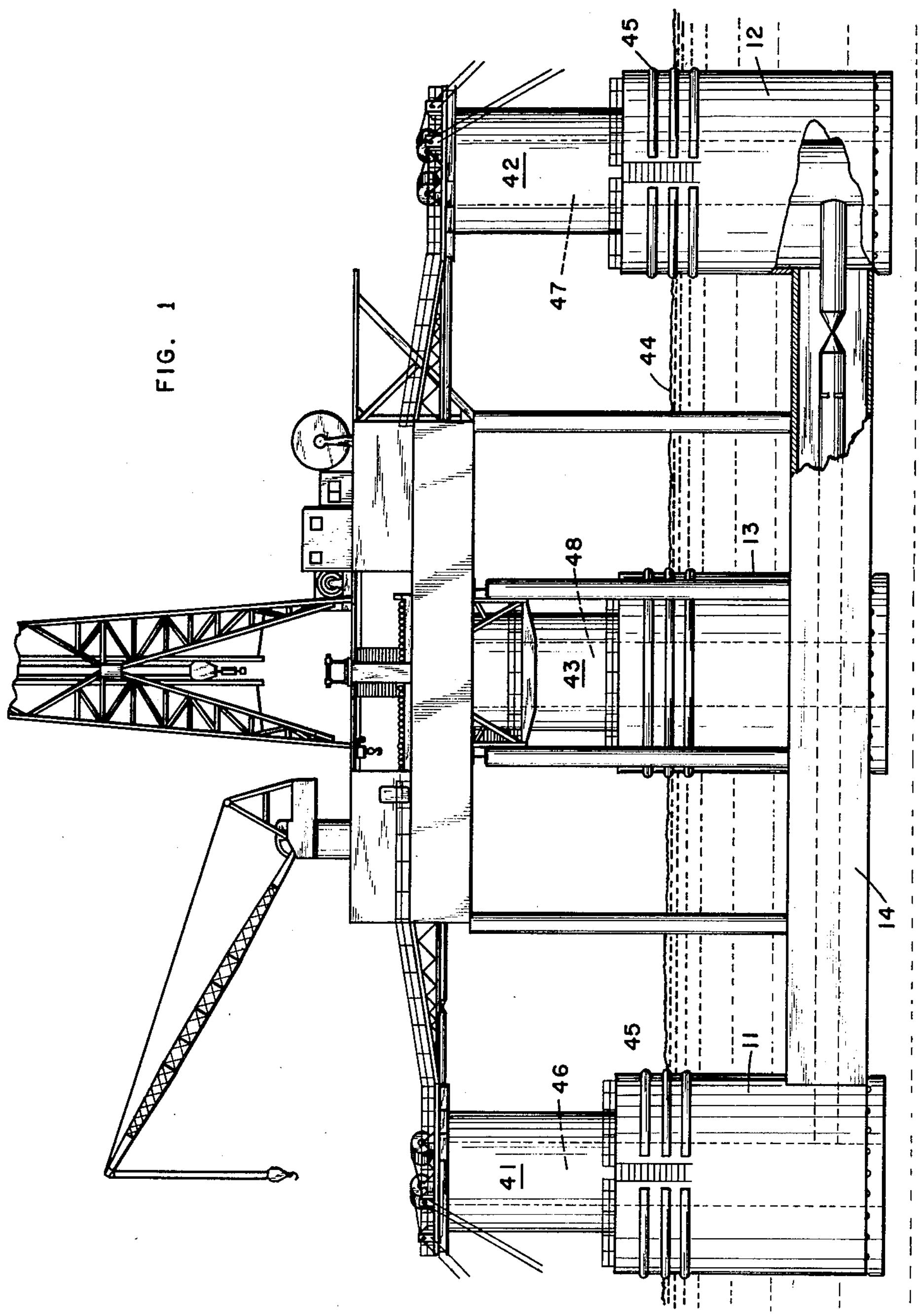
Dec. 8, 1964 D. DE VRIES 3,160,135

STABILIZING SYSTEM FOR FLOATING PLATFORM

Filed June 22, 1961 3 Sheets-Sheet 1

FIG. 1



INVENTOR:
D. de VRIES
BY: A. H. McCarthy
HIS AGENT

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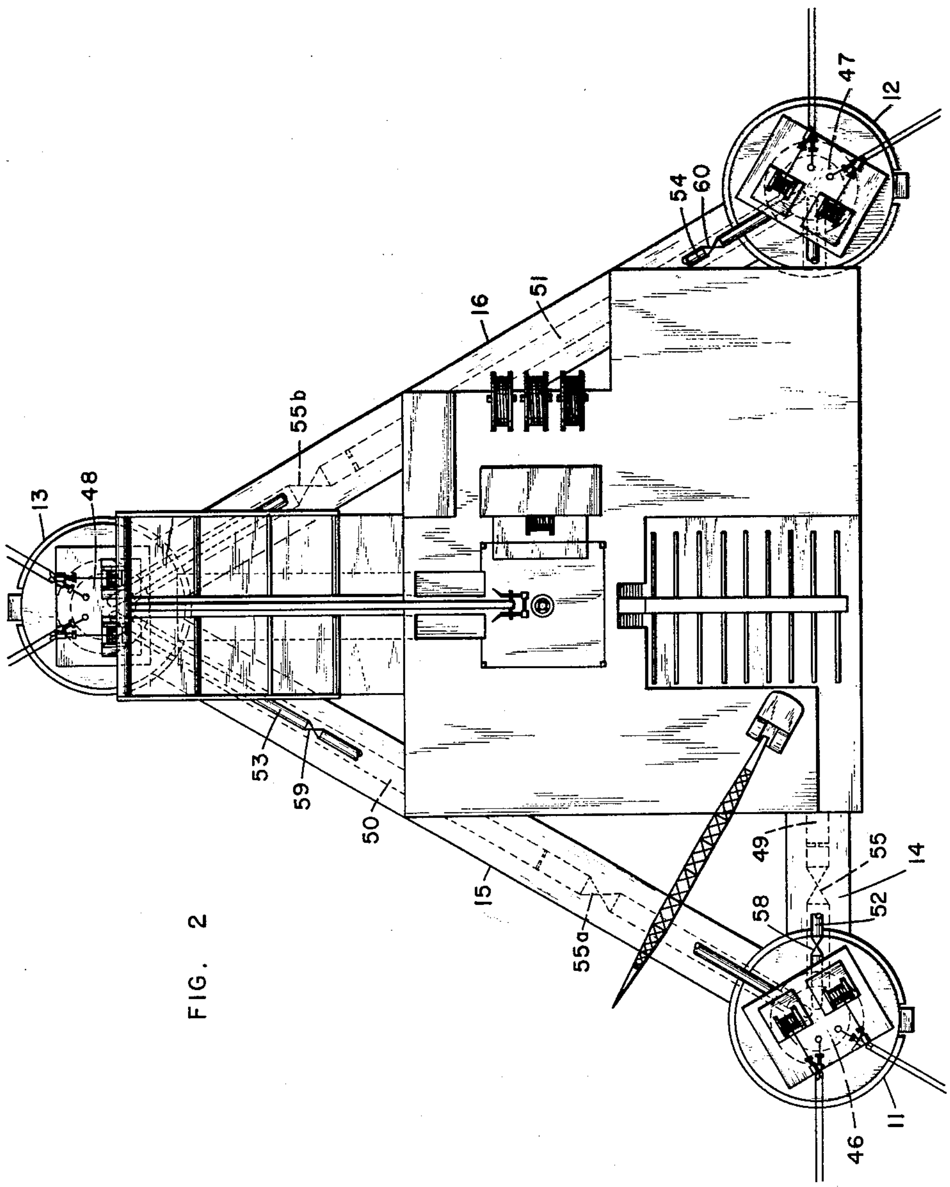

FIG. 2

INVENTOR:
D. de VRIES
BY: [signature]
HIS AGENT

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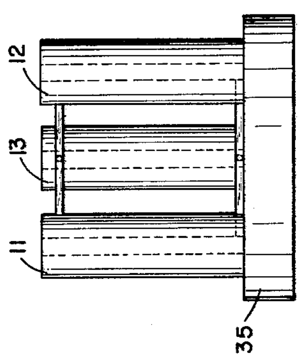

FIG. 5

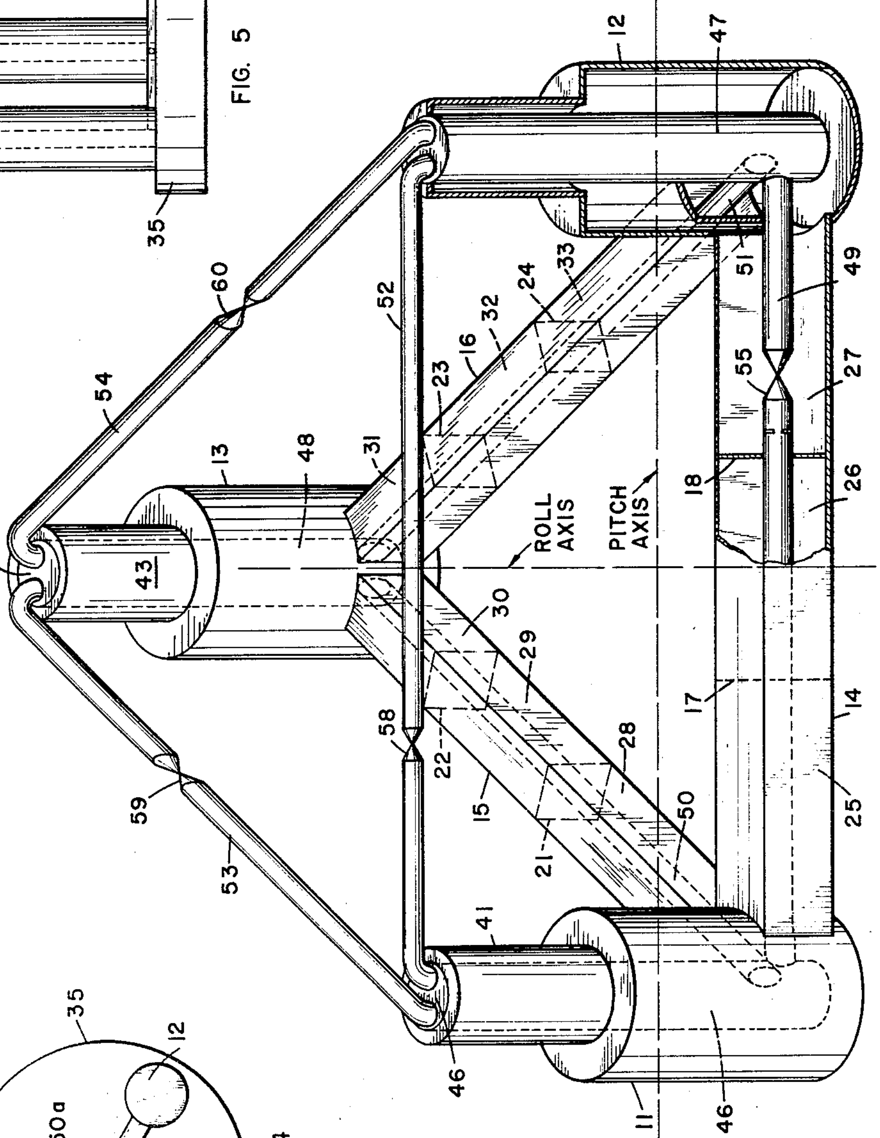

FIG. 3

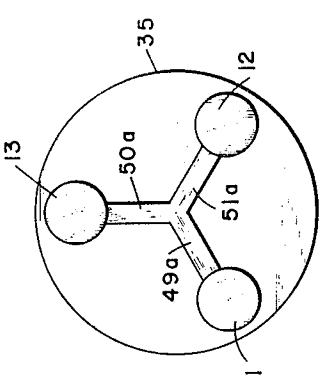

FIG. 4

INVENTOR:
D. de VRIES
BY: A. H. McCarthy
HIS AGENT

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3,160,135
STABILIZING SYSTEM FOR FLOATING PLATFORM

Douwe de Vries, Metairie, La., assignor to Shell Oil Company, New York, N.Y., a corporation of Delaware
Filed June 22, 1961, Ser. No. 118,988
4 Claims. (Cl. 114—125)

This invention relates to apparatus for use on the surface of a body of water while carrying out various operations such as exploration for oil, well drilling and completion operations, and well workover and maintenance operations. The invention pertains more particularly to apparatus for stabilizing a floating vessel or platform positioned in a substantially stationary manner at an offshore location for carrying out any of many operations therefrom.

In an attempt to locate new oil fields, an increasing amount of well drilling has been conducted at offshore locations, such for example as off the coasts of Louisiana, Texas and California. Well-drilling operations are being carried out further and further from shore in increasingly deeper water. At present, however, substantially all offshore well drilling is being conducted from a platform having legs affixed to the ocean floor, as by piling, or from mobile drilling platforms or barges having legs which may be extended downwardly through the water and in contact with the ocean floor in order to fixedly support the barge thereon. To date, using either of the two-above-described platforms, well-drilling operations have been limited to water depth of about 125 feet. The only known deep-water drilling that has been conducted to date has taken place from a converted boat in which a drilling well has been provided. Since boats and floating platforms are prone to roll fairly easily, deep-water drilling operations carried out from vessels of this type can only take place when wind and wave forces are fairly small. When drilling a well from a floating vessel, the vessel motions due to wave action introduced stresses in the drill pipe, tubing and casing strings used that often exceed the safe design stresses under certain weather conditions, thus causing drilling operations to be shut down.

It is therefore an object of the present invention to provide a system for stabilizing floating vessels such as those used in the exploration, drilling and completion of wells, whereby the motions of the vessel due to wave action may be dampened.

The motions of a floating vessel or platform due to wave actions can be divided into those in a horizontal plane (surge, sway and yaw) and those in a vertical plane (heave, roll and pitch). Roll and pitch are two different expressions connected with the geometry of the floating vessel, but are essentially the same type of motion. The general term "vertical angular motion" is used herein to describe these two motions and all combinations thereof. Another object of the present invention is to provide a closed passive stabilizing system designed to reduce the vertical angular motions (i.e., both the roll and pitch) due to wave action on a floating vessel.

Another object of the present invention is to provide a stabilizing system for a floating platform wherein the stabilizing system has a geometrical symmetry and is positioned on the vessel in a manner such that it is inde-

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pendent of the orientation of the plane of motion relative to the platform geometry, thus having an equal stabilizing effect for roll and pitch of the vessel.

A further object of the present invention is to provide a floating drilling or production platform of the semi-submersible type (one relying on freeboard for stability, but having much of its mass underwater) and provided with a stabilizing system from which drilling operations may be carried out economically and safely in deep waters.

Another object of the present invention is to provide a floating platform with a stabilizing system so that the platform can remain upright in hurricane weather without assistance of any mooring line forces.

Still another object of the present invention is to provide a stabilizing system for a floating platform designed to have a natural period of roll larger than that of the average period of waves to be encountered.

A further object of the present invention is to provide a floating drilling platform with a stabilizing system which substantially minimizes the roll and pitch of the platform thereby precluding subjecting drill pipe or casing to stresses as it hangs from the platform.

These and other objects of this invention will be understood from the following description taken with reference to the drawing, wherein:

FIGURE 1 is a view showing the outboard profile of the floating platform of the present invention in one form;

FIGURE 2 is a plan view of the floating platform of FIGURE 1;

FIGURE 3 is a diagrammatic isometric view of the hull portion of one form of the platform of the present invention;

FIGURE 4 is a diagrammatic plan view of another arrangement of the interconnecting conduit means of the stabilizing system of the present platform; and

FIGURE 5 is an outboard diagrammatic profile of the platform of FIGURE 4.

One form of a floating vessel or barge in which the stabilizing system of the present invention may be employed is described in copending application, Serial No. 111,847, filed May 22, 1961. Referring to FIGURE 1 of the drawing, the hull of the floating platform of the above-identified patent application comprises three vertically extending support or stabilizing columns 11, 12 and 13 which are interconnected in a closed triangular configuration by cross-bracing hull members 14, 15 and 16 which extend laterally between the stabilizing columns near the lower ends thereof. The cross-bracing hull members 14, 15 and 16 are preferably hollow, fluidtight members divided into a plurality of buoyancy tanks by means of watertight bulkheads as shown in FIGURE 3. Thus, hull member 14 may be provided with fluidtight bulkheads 17 and 18, while member 15 is provided with fluidtight bulkheads 21 and 22, and member 16 is provided with fluidtight bulkheads 23 and 24. This divides hull member 14 into buoyancy tanks 25, 26 and 27, hull member 15 into buoyancy tanks 28, 29 and 30, and hull member 16 into buoyancy tanks 31, 32 and 33. Although the hull of the floating vessel in FIGURES 1, 2 and 3 is shown as having a triangular configuration, it is to be understood that the stabilizing system of the present invention could be employed on a floating platform having a hull of any geometrical configuration, being rectangular, or round as shown in FIGURE 4, or any one which is preferably geometrically symmetrical. In addition, instead of the columns 11, 12 and 13 being interconnected by horizontal hull members 14, 15 and 16, the vertically extending stabilizing or support columns 11, 12 and 13 may be fixedly secured to a circular hull 35 shown in FIGURES 4 and 5, which may be divided by suitable bulkheads into any desired number of tanks either for purposes of buoyancy, or for storing materials such as water and fuel oil used during drilling operations.

The three corner support or stabilizing columns 11, 12 and 13 are preferably in the form of cylindrical tanks, as illustrated, which may be selectively flooded in order to lower the entire drilling platform in the water, thus stabilizing it by lowering its center of gravity. The stabilizing columns 11, 12 and 13 may be of the same diameter throughout their height, as illusrated in FIGURE 5 and may, for example, be 40 feet in diameter. However, the upper ends 41, 42 and 43 of the stabilizing columns 11, 12 and 13 are preferably reduced in diameter a substantial amount, say to 24 feet, a short distance above the water line when the floating platform is in its semi-submerged position, as illustrated in FIGURE 1. The diameter of the lower part of the stabilizing columns 11, 12 and 13 is large in order to reduce the amount of immersion which takes place when abnormally high hookloads are imposed on the floating platform through the fall lines and derrick. The upper ends 41, 42 and 43 of the stabilizing columns 11, 12 and 13 are reduced in size to decrease the wave force of the larger waves with heights in excess of a predetermined amount, say 10 feet.

The reduction in diameter of the upper ends 41, 42 and 43 of the support columns 11, 12 and 13 also provides the floating platform with a discontinual natural period of roll. When the floating platform rolls more than a predetermined amount, say past 5°, which occurs only in extremely high waves, the corner stabilizing column diameter suddenly changes from 40 feet to 24 feet as the natural period of roll increases from about 17 to 32 seconds. Therefore, if the floating platform were subjected to hurricane waves of a period of 17 seconds so that a resonance build-up occurs, the sudden increase in the natural period of roll from 17 to 32 seconds for roll angles about 5° would destroy any further resonant effects. Since the natural period of roll of the floating platform is a function of the water plane area of the stabilizing columns, a radical change in the natural period of roll of the platform takes place when a wave comes along to dip one supporting column below the surface of the water into the range of reduced diameter on the column. Since the period of the vessel and that of the waves are then different, resonance is destroyed and the amount of roll of the vessel immediately decreases.

The stabilizing columns 11, 12 and 13 serve as the primary ballast tanks with the tanks being filled substantially to the water level 44 when the vessel is positioned as shown in FIGURE 1. Each stabilizing column is provided with a series of circular steel fenders 45 to protect these members from damage by boats. Since the water level inside the stabilizing columns is nearly the same as that outside, a leak caused by a boat rupturing the wall of the column would not be serious. Since the buoyancy tanks 14, 15 and 16 are deeply submerged and support the weight of the platform there is little likelihood of their being damaged. Damage to the stabilizing columns would not affect the intact buoyancy tanks so that the platform would neither sink nor heel. The smaller diameter upper sections 41, 42 and 43 of the stabilizing columns 11, 12 and 13 are separated from columns 11, 12 and 13 by watertight bulkheads (not shown) which would prohibit further flooding of the stabilizing columns which might be damaged. Any suitable type of pumping and piping system may be employed for supplying water to and exacuating the stabilizing columns 11, 12 and 13 and/or any of the floodable buoyancy tanks.

The stabilizing system of the present invention comprises a series of three vertical tanks 46, 47 and 48 which are interconnected at the lower ends thereof by means of horizontal liquid flow lines or conduits 49, 50 and 51 by which the tanks 46, 47 and 48 are arranged in a closed triangular configuration, preferably that of an equilateral triangle. The liquid conduits 49, 50 and 51 are normally open at all times to permit liquid in the lower portions of the tanks to be readily transferred back and forth between tanks. In some cases the liquid conduits *49a*, *50a* and *51a* may be in the form shown in FIGURE 4.

The stabilizing system of the present invention is mounted on any suitable type of floating platform, two examples of which are illustrated in FIGURES 3 and 5. The basic hull plan of the floating platform illustrated in FIGURE 3 has the shape of an equilateral triangle and the approximate location of the center of gravity is on the vertical through the centroid of the triangle. For this floating platform the center of roll and pitch is approximately at the center of gravity, which "pitch" in this case being defined as the motion along an axis through the center of gravity parallel with one of the sides of the triangle, and "roll" as the motion around an axis through the center of gravity perpendicular to this side of the triangle. The vertical tanks 46, 47 and 48 are preferably located equidistance from each other and equidistance from a vertical line passing through the centroid of the floating platform, thus forming a three dimensional system designed to counteract effectively all angular vertical motions of the platform. The tanks 46, 47 and 48 are preferably provided with interconnecting air flow lines 52, 53 and 54 which are in communication with the interior of the tanks near the upper ends thereof, thus allowing air to be forced back and forth between the three tanks through the air lines 52, 53 and 54 as a liquid is transferred back and forth between the tanks through the liquid flow lines 49, 50 and 51.

In order to minimize construction costs on a platform similar to that illustrated in FIGURES 1 to 3, the tanks 46, 47 and 48 are installed within the support tanks 11, 12 and 13, although they may be positioned outside the tank. While the horizontal liquid flow lines 49, 50 and 51 are illustrated as being positioned in the horizontal hull members 14, 15 and 16, they may, in many circumstances, be positioned on the outside, preferably the top, of the hull members 14, 15 and 16 or at any distance thereabove or below. The exact position of the horizontal liquid flow lines 49, 50 and 51 with respect to the center of roll of the platform depends upon the stabilizing system being designed, and increasing stabilizing effect being realized when the horizontal flow lines 49, 50 and 51 are located higher in relation to the center of roll of the platform.

The rolling or pitching motion of an object on the surface of the ocean is greatest when resonance exists between object motion and wave action, i.e., when the wave frequency is qual to the natural frequency of roll or pitch of the object. In case of resonance the motion of the object will be 90° behind the wave action. The present stabilizing system provides a means of reducing roll or pitch of a floating platform. The principle of the system is based on resonance. The particular design of any stabilizing system of the present invention depends on the construction of characteristics of the floating platform and the normal conditions under which it is to be used. The stabilizing system of the present invention is designed in a manner such that a mass of stabilizing liquid in the tanks 46, 47 and 48 moves in resonance with the motion of the platform. When the mass of stabilizing liquid moves in resonance with the platform motion, and the platform motion is in resonance with the wave action, the stabilizing fluid motion is 90° behind the platform motion and 180° behind, and therefore opposed to, the wave action. Since wave action is the driving force causing the original roll or pitch of the platform, an opposing action by a mass of stabilizing liquid moving between tanks 46, 47 and 48 tends to reduce or dampen any angular vertical motion of the platform. A stabilizing system in accordance with the present invention can be designed for any floating object with known properties and known performance under wave action. The length and cross-sectional design and dimensions of the vertical tanks or the interconnecting horizontal liquid flow lines 49, 50 and 51 may be varied considerably depending upon the platform design on which the present stabilizing system is to be employed.

In any vessel the stabilizing water motion between the tanks 46, 47 and 48 is tuned to the motion of the platform, that is, the natural period of stabilizing liquid movement is equal to that of the platform. While a stabilizing system in accordance with the present invention may be designed so that its natural period is equal to the natural period of roll of the platform on which it is to be employed, the liquid flow lines 49, 50 and 51 are each preferably provided with suitable liquid flow controlling means, such as a valve 55, or other adjustable flow controlling devices which are preferably power actuated and remotely controlled. The air lines 52, 53 and 54 are also preferably provided with flow controlling devices such as power-actuated remotely-controlled valves 58, 59 and 60. While the floating vessel of FIGURE 3 is illustrated and described as being equipped with air flow lines 52, 53 and 54 in communication between tanks 46, 47 and 48, it is to be understood that the tops of the tanks 46, 47 and 48 may be provided with any suitable type of air intake and discharge ports which are preferably closable by suitable valve means. By closing the air valves 58, 59 and 60 in the air lines 52, 53 and 54, the flow of stabilizing liquid between the tanks 46, 47 and 48 may be stopped. By partial closure of the valves 58, 59 and 60, the stabilizing water motion can be restricted to stay within the available height of the vertical tanks 46, 47 and 48. The energy contained in the moving column of water as it enters any of the vertical tanks 46, 47 and 48 is then dissipated in compressing the air at the top of the tank. This is preferable to letting the stabilizing water column hit the top of the vertical tank in a manner such that energy would be dissipated in a considerable instantaneous force on the vessel. If desired, the air intake and discharge ports in the tops of the tanks 46, 47 and 48, or the interconnecting air lines 52, 53 and 54, may be eliminated with air being trapped in the tops of the tanks.

The use of the flow-controlling valves 55 and the air valves 58, 59 and 60 is also important so that movement of the stabilizing liquid in the tanks 46, 47 and 48 may be stopped when it would tend to amplify the motion of the platform rather than dampen the motion. Amplification of the motion of the platform occurs when the wave motion period is considerably longer than the natural periods of the platform and the stabilizing liquid carried in tanks 46, 47 and 48. In the extreme case of very long wave periods, all of the stabilizing water in the tanks 46, 47 and 48 would flow to the low side of the platform, which under these conditions would tend to move at the wave frequency rather than at its own natural period. In an emergency, where amplification of motion or stationary list of the platform occurs, the control valves in the horizontal fluid flow lines and air lines between the vertical tanks 46, 47 and 48 could be closed. Preferably a suitable pumping and piping arrangement would be provided to eliminate the free-water surface of the stabilizing system when so desired, by discharging all fluid from the vertical tanks 46, 47 and 48. This same arrangement would also serve to fill the system to its operating capacity.

For a floating platform similar to that illustrated in FIGURE 3, each vertical tank 46, 47 and 48 may be 70 feet in height and about 6½ feet in diameter with the interconnecting horizontal lines being 4 feet in diameter and the tanks 46, 47 and 48 being 200 feet apart. By use of the stabilizing system of the present invention, a reduction of 60% or more in the vertical angular motions of a stationary floating platform can be realized when platforms of this type exhibit a large amplitude of roll or pitch. Although sea water is generally used in the stabilizing system, the use of higher density liquids in the tanks results in larger stabilizing effects on a platform. Thus, in some cases it is preferable to employ a weighted stabilizing fluid so that other dimensions of the system could be altered. The amount of stabilizing fluid in the vertical tanks 46, 47 and 48 is preferably adjusted so that there is at least some liquid at all times in the bottom of each of the tanks.

I claim as my invention:

1. A floating vessel comprising a buoyant hull, three upwardly-extending fluid tanks fixedly secured to the hull of said vessel and arranged in a substantially equilateral triangular configuration about a vertical line through the centroid of said vessel, said tanks being partially filled with a liquid, normally liquid-filled laterally-extending conduit means interconnecting the lower portions of said upwardly-extending fluid tanks to permit continual flow of liquid between said tanks, at least a portion of said laterally-extending conduit means having a cross-section sufficient to delay the flow of water through the conduit means so that the velocity of the fluid lags 90° behind the rotational velocity of the vessel, and air intake and discharge means in the upper end of each of said tanks.

2. A floating vessel comprising a buoyant hull, three upwardly-extending fluid tanks fixedly secured to the hull of said vessel and arranged in a substantially equilateral triangular configuration about a vertical line through the centroid of said vessel, said tanks being partially filled with a liquid, normally liquid-filled laterally-extending first conduit means interconnecting the lower portions of said upwardly-extending fluid tanks to permit continual flow of liquid between said tanks, at least a portion of said laterally-extending conduit means having a cross-section sufficient to delay the flow of water through the conduit means so that the velocity of the fluid lags 90° behind the rotational velocity of the vessel, air intake and discharge means in the upper end of each of said tanks, and second conduit means in communication with said air intake and discharge means for interconnecting the upper portions of said tanks.

3. A floating vessel comprising a buoyant hull, three upwardly-extending fluid tanks fixedly secured to the hull of said vessel and arranged in a substantially equilateral triangular configuration about a vertical line through the centroid of said vessel, said tanks being partially filled with a liquid, normally liquid-filled laterally-extending first conduit means interconnecting the lower portions of said upwardly-extending fluid tanks to permit continual flow of liquid between said tanks, at least a portion of said laterally-extending conduit means having a cross-section sufficient to delay the flow of water through the conduit means so that the velocity of the fluid lags 90° behind the rotational velocity of the vessel, air intake and discharge means in the upper end of each of said tanks, second conduit means in communication with said air intake and discharge means for interconnecting the upper portions of said tanks, and fluid flow control means in said first conduit means.

4. A floating vessel comprising a buoyant hull, three upwardly-extending fluid tanks fixedly secured to the hull of said vessel and arranged in a substantially equilateral triangular configuration about a vertical line through the centroid of said vessel, said tanks being partially filled with a liquid, normally liquid-filled laterally-extending first conduit means interconnecting the lower portions of said upwardly-extending fluid tanks to permit continual flow of liquid between said tanks, at least a portion of said laterally-extending conduit means having a cross-

section sufficient to delay the flow of water through the conduit means so that the velocity of the fluid lags 90° behind the rotational velocity of the vessel, air intake and discharge means in the upper end of each of said tanks, second conduit means in communication with said air intake and discharge means for interconnecting the upper portions of said tanks, first fluid flow control means in said first conduit means and second fluid flow control means in said second conduit means, said first fluid flow control means being normally open at all times whereby fluid in said tanks may move from one tank to another.

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