

PATENT SPECIFICATION

(11) 1 603 224

1 603 224

- (21) Application No. 12371/78 (22) Filed 30 March 1978
(31) Convention Application No. 787 756
(32) Filed 15 April 1977
(31) Convention Application No. 831 894
(32) Filed 9 Sept. 1977 in
(33) United States of America (US)
(44) Complete Specification published 18 Nov. 1981
(51) INT CL³ B63B 39/02
(52) Index at acceptance B7V EB



(54) SYSTEM FOR STABILIZING A FLOATING VESSEL

(71) We, SEATEK CORPORATION, of 5383 Hollister Avenue, Santa Barbara, California 93111, United States of America, a corporation organised and existing under the laws of the State of California, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention is concerned with improvements in or relating to systems for stabilizing floating vessels.

Seagoing vessels are required in various types of offshore operations, including scientific surveys and oil and gas drilling and production. Such vessels are typically configured as drillships, barges and jack-up rigs, as well as supply and service ships.

Both active and passive techniques have been proposed for damping the natural oscillatory displacement of vessels to achieve roll and pitch stabilization in seas having periodic wave motion. Such techniques have utilized water tanks on the vessels and various arrangements of blowers, pumps, valves, valve actuators, roll and pitch sensors, and electronic control circuits for moving water in the tanks to counteract oscillatory roll and pitch motion. A common objective of heretofore known systems has been to make the natural frequency of oscillatory flow of water in the tanks approximately the same as the natural frequency of oscillations of the vessel, thereby to "tune" the tanks to the vessel. Once tuned, the damping action is achieved by causing the flow pattern of water in the tanks to be approximately 90° out of phase with the natural oscillations of the vessel. The forces produced by the water in the tanks then tend to counteract the roll and pitch forces on the vessel.

Prior systems that attempt to achieve stabilization in the manner described above have the disadvantage that large counteracting, damping forces must be produced in order for the system to be effective. The equipment required to provide the large counteracting forces is complex and expensive. In active

systems, high power blowers and pumps are typically required. Passive systems generally require high capacity valves, special stabilizing tank configurations and control circuits for timing the flow of water in the tanks.

The present invention provides in a floating vessel a passive system for stabilizing the vessel comprising a plurality of tanks disposed on the vessel below the water line, each of the tanks having an opening and being dimensioned to fill and drain with ambient water substantially in phase with oscillatory vessel motion relative to the surface of the water during each cycle of said oscillatory motion; conduit means interconnecting at least two tanks near the tops thereof for providing a passive airway therebetween; and means coupled to said conduit means for selectively pressurizing said tanks and said conduit means to permit selected water levels to be attained in said tanks during oscillatory motion of said vessel for reducing the righting moment of said vessel and lengthening the period of oscillation of said vessel beyond the period of waves acting on the vessel.

In a system as set forth in the last preceding paragraph, said tanks may be disposed on the bottom of said vessel.

In a system as set forth in the last preceding paragraph or the last preceding paragraph but one, it is preferred that the tank height dimension of each of said tanks is selected to permit complete filling and draining of each tank during a portion of a cycle of oscillatory motion of the vessel thereby to prevent capsizing of the vessel by causing the righting moment thereof to increase as rapidly as a function of additional angular displacement of the vessel during the portion of the cycle that one of said tanks is completely filled.

In a system as set forth in any one of the last three immediately preceding paragraphs, it is preferred that said vessel has an axis of symmetry and said tanks are disposed in spaced-apart pairs on opposite sides of said axis.

In a system as set forth in the last preceding paragraph, it is preferred that said conduit means provides a separate air passageway be-

tween each of said pairs of tanks.

In a system as set forth in the last preceding paragraph, it is preferred that said conduit means includes a continuous open pipe interconnecting each of said pairs of tanks.

In a system as set forth in any one of the last six immediately preceding paragraphs, it is preferred that said means for selectively pressurizing said tanks provides adjustable air pressure therein to permit water to completely fill one of said tanks during a portion of a cycle of oscillatory motion of the vessel for preventing capsizing of the vessel by causing the righting moment thereof to increase rapidly as a function of additional angular displacement of the vessel during the portion of the cycle that the tank is completely filled.

In a system as set forth in the last preceding paragraph, it is preferred that said means for providing air pressure in said tanks includes an air pump and valve means for isolating said air pump from said conduit means.

In a system as set forth in the last preceding paragraphs but six, the tanks may be disposed within the hull of the vessel. Alternatively, the tanks may be disposed on the sides of the hull of the vessel and may be disposed partially within the hull.

The present invention further provides a passive method for stabilizing a seagoing vessel having two tanks disposed on said vessel below the water line on opposite sides of an axis of symmetry of said vessel, the method comprising the steps of filling one of said tanks to a first water level in phase with the travel of said tank into the sea during a cycle of oscillatory vessel motion; and simultaneously draining the other of said tanks to a second water level in response to the filling of said one tank during the same cycle of oscillatory vessel motion by directing air forced out of said one tank being filled into said other tank through conduit means defining a passive air passageway; thereby to reduce the righting moment of said vessel and lengthen the period of oscillation of said vessel beyond the wave period of the sea.

A method as set forth in the last preceding paragraph may include pressurizing said two tanks and said conduit means with a predetermined air pressure to select said first and second water levels attained in said tanks during the filling and draining steps respectively.

A method as set forth in the last preceding paragraph or the last preceding paragraph but one may include completely filling each tank upon predetermined travel into the sea, thereby to prevent capsizing of the vessel by causing the righting moment thereof to increase rapidly as a function of additional angular displacement of the vessel when the tank is completely filled.

A method as set forth in the last preceding paragraph but one or the last preceding paragraph but two may include completely filling

each tank in response to predetermined angular displacement of the vessel about its axis of symmetry to rapidly increase the righting moment thereof as a function of additional angular displacement and prevent capsizing of the vessel when the tank is completely filled.

The present invention further provides in a vessel having an axis of symmetry a passive system for stabilizing the vessel comprising a plurality of tanks disposed on said vessel in spaced apart pairs on opposite sides of said axis and below the water line, each of said tanks having a bottom portion substantially completely open to the sea and being dimensioned to fill and drain in phase with oscillatory vessel motion relative to the surface of the sea during each cycle of said oscillatory motion; conduit means coupled to the top surfaces of said tanks for providing separate passive air passageways between each of said pairs of tanks, and said conduit means including a continuous open pipe interconnecting each of said pairs of tanks; means coupled to said conduit means for providing a selected air pressure in said tanks and said conduit means to permit selected water levels to be attained in said tanks during oscillatory motion of said vessel, thereby to reduce the righting moment of said vessel and lengthen the period of oscillation of said vessel beyond the wave period of the sea.

In a system as set forth in the last preceding paragraph, it is preferred that said tanks are disposed on the bottom of said vessel.

In a system as set forth in the last preceding paragraph or the last preceding paragraph but one, it is preferred that the tank height dimension of each of said tanks is selected to permit complete filling and draining of each tank during a portion of a cycle of oscillatory motion of the vessel, thereby to prevent capsizing of the vessel by causing the righting moment thereof to increase rapidly as a function of additional angular displacement of the vessel during the portion of the cycle that one of said tanks is completely filled.

In a system as set forth in any one of the last three immediately preceding paragraphs, it is preferred that said means for providing air pressure in said tanks is adjustable to permit water to completely fill the tanks on one side of said axis during a portion of a cycle of the oscillatory motion of said vessel.

In a system as set forth in any one of the last four immediately preceding paragraphs, it is preferred that said means for providing air pressure in said tanks includes an air pump and valve means for isolating said air pump from said conduit means.

In a system as set forth in any one of the last five immediately preceding paragraphs, it is preferred that each of said tanks is disposed on the hull of the vessel with at least a portion of the tank positioned outside the contour of the hull.

70

75

80

85

90

95

100

105

110

115

120

125

130

15

In a system as set forth in the last preceding paragraph, it is preferred that said tanks are positioned entirely outside the contour of the hull of the vessel.

5 In a system as set forth in the last preceding paragraph but three or the last preceding paragraph but four, it is preferred that each completely filled tank is a tank on the side of the axis of symmetry of the vessel toward
10 which the vessel is heeling.

The present invention provides stabilization of a seagoing vessel with a passive system which does not rely on the use of tanks having a natural period which is substantially the same as the natural oscillatory period of the vessel to produce large counteracting forces that damp the angular motion of the vessel. Instead, tanks are used for the purpose of reducing the righting moment of the vessel as described below.

20 In accordance with illustrated embodiments of the invention, water tanks are disposed on opposite sides of the longitudinal axis of symmetry of the vessel. The tanks are located below the water line, preferably on or near the bottom of the hull of the vessel. The tanks have a shallow configuration, with larger horizontal dimensions than vertical dimensions. The bottom portion of each tank is substantially open to the sea to permit sea water to rapidly fill and drain from the tanks in short time periods which are generally much shorter than the period of natural oscillatory motion of the vessel. An open conduit interconnects the tanks to provide a continuous air passageway between them. An air pump is coupled to the conduit to pressurize the tanks to a preselected pressure level for selectably controlling the water levels in the tanks during oscillatory wave motion.

40 In operation, the water tanks alternately and continuously fill and drain in synchronism with oscillatory wave motion. For example, as the vessel tends to roll clockwise on its central longitudinal axis, the tank on the right side of the vessel will quickly fill through its large bottom opening. Air is forced out of this tank through the conduit and into the tank on the left side of the vessel. The increased air volume in the left tank rapidly forces water out of it. As the vessel tends to roll counterclockwise, the left tank fills and the right tank is forced to drain under the force of the air pressure in the system.

55 The present invention acts to reduce the righting moment of the vessel in a periodic sea. For example, as the vessel tends to roll in one direction, the system reduces the tendency of the vessel to restore itself to an upright position. The reduction of the righting moment lengthens the period of oscillation of the vessel beyond the wave period of the sea. This in turn substantially reduces the amplitude of the roll.

65 There now follows a detailed description

which is to be read with reference to the accompanying drawings of a system and method according to the invention; it is to be clearly understood that this system and method have been selected for description to illustrate the invention by way of example and not by way of limitation.

In the accompanying drawings:—

Figure 1 is a side view of a vessel illustrating one embodiment of the stabilizing tanks of a system constructed according to the principles of the present invention;

Figure 2 is a bottom view of the vessel of Figure 1 illustrating the location and coupling of the stabilizing tanks;

Figures 3A—3D are diagrammatic end views of the vessel of Figure 1 illustrating alternative embodiments of a stabilizing system constructed according to the principles of the present invention;

Figure 4 is a diagrammatic end view of the vessel of Figure 1 illustrating the operation of one embodiment of a system constructed according to the principles of the present invention; and

Figure 5 is a graph illustrating the magnitude of the ratio of roll amplitude to wave slope as a function of the period of wave motion for vessels with and without a system constructed according to the principles of the present invention.

Referring now to Figures 1, 2 and 3A, there is shown a vessel 11 in the form of a barge of the type used in offshore oil drilling operations. Disposed below the water line 13, on the bottom of the barge 11 are two elongated tanks 15, 17. The tanks 15, 17 respectively have bottom portions generally designated at 19, 21 (Figure 3A). These bottom portions 19, 21 are preferably substantially open to the sea; however, alternatively the bottom portions may be covered by a perforated plate or grating to provide greater structural strength. The tanks 15, 17 each have a shallow configuration, with larger horizontal dimensions than vertical dimensions. With this arrangement, sea water may fill and drain from the tanks very rapidly. More particularly, the tanks must be configured so as to permit filling and draining during time periods which are much shorter than the time required for the barge to complete one cycle of natural oscillatory roll or pitch motion in a periodic sea.

As shown in Figure 2, the barge 11 has a longitudinal axis of symmetry 22. The tanks 15, 17 are disposed symmetrically in spaced-apart relation on opposite sides of the axis 22 and are coupled together by a conduit 23 shown diagrammatically in Figure 3A. The conduit 23 is in the form of a continuous, open pipe providing an air passageway between the tanks. One end of the conduit 23 is connected through a port to the top surface of the tank 15, while the other end of the conduit 23 is

connected through a port to the top surface of the tank 17. Means including an air pump or blower 25 and air valve 27 are coupled to the conduit 23 to provide air pressure in the conduit and tanks 15, 17. The conduit 23 and tanks 15, 17 form a closed system, and the air pressure therein may be selected by opening valve 27 and operating pump 25 until a desired air pressure is reached. Thereafter, the valve 27 is closed. Alternatively, the valve 27 may be eliminated or left open and the air pump 25 continuously operated at a selected rate to maintain the desired air pressure in the system. Preferably the air pressure is adjusted until sea water is permitted to fill the tanks alternately during oscillatory wave motion, as hereinafter described.

As shown in Figure 2, each of the tanks 15, 17 may be divided into a plurality of separate compartments. The tank 15 may comprise six compartments A, B, C, D, E, and F, each isolated from the other by intermediate walls represented by dashed lines 29. Similarly, the tank 17 may comprise six separate compartments A', B', C', D', E' and F', isolated by walls 31. The compartments are disposed in spaced-apart symmetrical pairs on opposite sides of the longitudinal axis 22, the pairs comprising compartments A, and A', B and B', etc. Compartmentalization of the tanks 15, 17 serves to minimize excitation of waves and undesirable consequent wave forces on the free water surface contained inside the tanks.

Each pair of compartments is coupled by separate conduit means, generally indicated by dashed outline pipes 33. Thus, the pair of compartments A, A' is coupled in a closed pressurized system as shown in Figure 2. The other pairs of compartments are similarly separately coupled. A common blower and ducting arrangement (not shown) may be used to supply air pressure to all pairs of compartments.

The desired reduction of the righting moment when the vessel is caused to heel is a consequence of sea water entering a tank on one side of the vessel and leaving a tank on the opposite side of the vessel in approximately equal quantities as a result of the existence of an open connecting air-filled duct. Thus, the location and configuration of the tanks 15 and 17 may be varied as shown in Figures 3B, 3C and 3D (pump 25 and valve 27 not being shown). Figure 3B shows the tanks on the bottom but within the hull of the vessel. This arrangement may be preferred for incorporating into new vessels during construction. Figure 3C shows the tanks 15 and 17 outside and at the sides of the hull, at or near the bottom. This, as well as the configuration of Figure 3A, may be preferred for retrofitting existing vessels since the integrity of the original hull is left essentially unchanged. Figure 3D shows still another embodiment wherein tanks 15 and 17 are partially

inside and partially outside the hull of the vessel, at or near the bottom.

All four configurations are based on the same principle that, as the vessel is caused to heel, water enters the tank on the depressed side and departs from the tank on the opposite elevated side. This shift of the ballast water volumes in the tanks leads to a heeling torque acting in the same direction as the applied torque. The required applied torque for a given heeling angle is therefore reduced. The restoring torque is in other words reduced, and the natural period of roll lengthened.

Operation of the systems of Figures 1—3D may be understood by reference to Figures 3A and 4. As shown in Figure 3A, the tanks 15, 17 of the vessel 11 are initially pressurized by the air pump 25 so that sea water fills about one-half of each tank in a quiet sea, as indicated by the water surfaces 35. As the vessel 11 tends to roll about the axis 22 in a clockwise direction, as shown in Figure 4, the tank 17 will fill with water, thus driving air out of the tank 17 through the conduit 23 and into the tank 15. The increasing volume of air in the tank 15 forces water to drain from the tank and lowers the level of the water surface 35 to a new level 37. During this operation, either the valve 27 is closed, or the valve 27 is open and the pump 25 is running to maintain constant air pressure in the tanks and conduit. Thus, the volume of air displaced from the tank 17 is transferred to the tank 15. When roll displacement is counterclockwise, the tank 15 is filled and the tank 17 is drained in the same manner as described above.

The filling of the tank 17 with water as the vessel 11 tends to roll clockwise has the effect of reducing the righting moment of the vessel. In other words, the tendency of the vessel to return to an upright condition after a roll is commenced will be reduced, thus making the oscillatory roll motion of the vessel more sluggish. The roll period of the vessel is lengthened. In a typical sea where the wave motion has a seven second period, the roll period of the vessel produced by the system of the present invention is preferably lengthened to about twelve seconds. Since the roll period of the vessel is substantially longer than the period of wave motion, the waves have a greatly diminished effect on the vessel.

The reduction in righting moment of the vessel in a quiet sea by a system constructed according to the principles of the present invention will also reduce roll torque in a sea having periodic wave motion. The tanks 15, 17 are dimensioned such that when air has been pumped into them, there is still a positive metacentric height (i.e., a positive righting moment). During operation in a periodic sea, there may be a tendency for the vessel 11 to overturn if the righting moment is reduced too much. This is especially true if the vessel is

subjected to strong winds. A significant safety feature of a system constructed according to the principles of the present invention is that the tank height dimension and initial quiescent water level within the tank (e.g., the tank 17) are selected so that, during a very large roll of the vessel, the tank fills completely. Once the tank is filled, the normal buoyancy forces on the vessel are restored and the righting moment increases rapidly as a function of additional angular roll displacement which prevents capsizing of the vessel.

For the tank configuration shown in Figures 3C and 3D the open-bottom tanks are external underwater sponsons. The tanks are pressurized by air. Vessel rolling or the incidence of a wave causes the water in the tanks to rise and fall so that the restoring torque (i.e., righting moment) is reduced and the natural period of roll lengthened, as described earlier in this specification. In these cases, however, torques arising from wave-induced forces on the top-sides of the wetted tanks oppose the torques generated by wave forces on the hull itself. The net result is a reduction of the total wave-induced torques on the vessel just as for the internal tank configuration.

Figure 5 illustrates by comparison the effect of a reduced righting moment on vessel 11 produced by a system constructed according to the principles of the present invention. Curve 37 shows the ratio of roll amplitude to wave slope for a vessel which is not stabilized; whereas curve 39 illustrates the roll amplitude characteristic for the vessel 11 stabilized according to the principles of the invention. The unstabilized vessel has a roll amplitude characteristic with a resonant peak at seven seconds. Wave motion in an open sea also typically has a seven second period. Thus, without stabilization the vessel will have a roll amplitude which is at or near the maximum point P of its resonant peak. In contrast, the stabilized vessel 11 has a resonant peak which occurs at about a twelve second period, which is substantially longer than the typical seven second wave period in an open sea. Thus, for seven second waves, the stabilized vessel will operate at point S on curve 39, and the roll amplitude will be reduced to less than one-sixth of what it was in the unstabilized vessel.

The vessel 11 is a barge about 375 feet long. Each of the tanks 15, 17 is about 275 feet long and divided into several compartments of equal size. The width of each tank is 10 to 12 feet, and its height is 6 to 7 feet. The conduits 23 which connect the compartments of the tanks are each about 3 to 4 feet in diameter.

Although the vessel 11 is shown as a barge, other types of vessels may be stabilized utilizing the principles of the present invention. For example, such a stabilization system may be applied to triangular or rectangular shaped jack-up oil drilling rigs. The tanks may be

symmetrically disposed with respect to the geometric center of the vessel (e.g. at the vertices of a triangular shaped rig or at the corners of a rectangular rig). In order to stabilize against both roll and pitch, all tanks may be coupled in common through conduits to a source of air pressure. With this arrangement both roll and pitch righting moments are reduced.

WHAT WE CLAIM IS:—

1. In a floating vessel a passive system for stabilizing the vessel comprising:

a plurality of tanks disposed on the vessel below the water line, each of the tanks having an opening and being dimensioned to fill and drain with ambient water substantially in phase with oscillatory vessel motion relative to the surface of the water during each cycle of said oscillatory motion;

conduit means interconnecting at least two tanks near the tops thereof for providing a passive airway therebetween; and

means coupled to said conduit means for selectively pressurizing said tanks and said conduit means to permit selected water levels to be attained in said tanks during oscillatory motion of said vessel for reducing the righting moment of the vessel and lengthening the period of oscillation of said vessel beyond the period of waves acting on the vessel.

2. A system according to claim 1 wherein said tanks are disposed on the bottom of said vessel.

3. A system according to either one of claims 1 and 2 wherein the tank height dimension of each of said tanks is selected to permit complete filling and draining of each tank during a portion of a cycle of oscillatory motion of the vessel thereby to prevent capsizing the vessel by causing the righting moment thereof to increase rapidly as a function of additional angular displacement of the vessel during the portion of the cycle that one of said tanks is completely filled.

4. A system according to any one of the preceding claims wherein said vessel has an axis of symmetry and wherein said tanks are disposed symmetrically in spaced-apart pairs on opposite sides of said axis.

5. A system according to claim 4 wherein said conduit means comprises a respective air passageway between each of said pairs of tanks.

6. A system according to claim 5 wherein said passageway includes a continuous open pipe.

7. A system according to any one of the preceding claims wherein said means for selectively pressurizing said tanks provides adjustable air pressure therein to permit water to completely fill one of said tanks during a portion of a cycle of oscillatory motion of the vessel for preventing capsizing of the vessel by causing the righting moment thereof to in-



5 subjected to strong winds. A significant safety
feature of a system constructed according to
the principles of the present invention is that
the tank height dimension and initial quiescent
water level within the tank (e.g., the tank 17)
are selected so that, during a very large roll
of the vessel, the tank fills completely. Once
the tank is filled, the normal buoyancy forces
on the vessel are restored and the righting
moment increases rapidly as a function of
10 additional angular roll displacement which
prevents capsizing of the vessel.

For the tank configuration shown in Figures
3C and 3D the open-bottom tanks are external
underwater sponsons. The tanks are pressurized
by air. Vessel rolling or the incidence of a
wave causes the water in the tanks to rise and
fall so that the restoring torque (i.e., righting
moment) is reduced and the natural period
20 of roll lengthened, as described earlier in this
specification. In these cases, however, torques
arising from wave-induced forces on the top-
sides of the wetted tanks oppose the torques
generated by wave forces on the hull itself.
25 The net result is a reduction of the total
wave-induced torques on the vessel just as for
the internal tank configuration.

Figure 5 illustrates by comparison the effect
of a reduced righting moment on vessel 11
30 produced by a system constructed according
to the principles of the present invention.
Curve 37 shows the ratio of roll amplitude to
wave slope for a vessel which is not stabilized;
whereas curve 39 illustrates the roll amplitude
35 characteristic for the vessel 11 stabilized
according to the principles of the invention.
The unstabilized vessel has a roll amplitude
characteristic with a resonant peak at seven
seconds. Wave motion in an open sea also
40 typically has a seven second period. Thus,
without stabilization the vessel will have a
roll amplitude which is at or near the maxi-
mum point P of its resonant peak. In contrast,
the stabilized vessel 11 has a resonant peak
45 which occurs at about a twelve second period,
which is substantially longer than the typical
seven second wave period in an open sea. Thus,
for seven second waves, the stabilized vessel
will operate at point S on curve 39, and the
50 roll amplitude will be reduced to less than one-
sixth of what it was in the unstabilized vessel.

The vessel 11 is a barge about 375 feet
long. Each of the tanks 15, 17 is about 275
feet long and divided into several compart-
ments of equal size. The width of each tank
is 10 to 12 feet, and its height is 6 to 7 feet.
55 The conduits 23 which connect the compart-
ments of the tanks are each about 3 to 4 feet
in diameter.

60 Although the vessel 11 is shown as a barge,
other types of vessels may be stabilized utiliz-
ing the principles of the present invention.
For example, such a stabilization system may
be applied to triangular or rectangular shaped
65 jack-up oil drilling rigs. The tanks may be

symmetrically disposed with respect to the
geometric center of the vessel (e.g. at the
vertices of a triangular shaped rig or at the
corners of a rectangular rig). In order to stabi-
lize against both roll and pitch, all tanks may
70 be coupled in common through conduits to
a source of air pressure. With this arrange-
ment both roll and pitch righting moments
are reduced.

WHAT WE CLAIM IS:—

1. In a floating vessel a passive system for
stabilizing the vessel comprising:

a plurality of tanks disposed on the vessel
below the water line, each of the tanks having
an opening and being dimensioned to fill and
80 drain with ambient water substantially in phase
with oscillatory vessel motion relative to the
surface of the water during each cycle of said
oscillatory motion;

conduit means interconnecting at least two
85 tanks near the tops thereof for providing a
passive airway therebetween; and

means coupled to said conduit means for
selectively pressurizing said tanks and said
conduit means to permit selected water levels
90 to be attained in said tanks during oscillatory
motion of said vessel for reducing the righting
moment of the vessel and lengthening the
period of oscillation of said vessel beyond the
period of waves acting on the vessel.

2. A system according to claim 1 wherein
said tanks are disposed on the bottom of said
vessel.

3. A system according to either one of
claims 1 and 2 wherein the tank height dimen-
sion of each of said tanks is selected to permit
complete filling and draining of each tank
during a portion of a cycle of oscillatory mo-
tion of the vessel thereby to prevent capsizing
105 the vessel by causing the righting moment
thereof to increase rapidly as a function of
additional angular displacement of the vessel
during the portion of the cycle that one of
said tanks is completely filled.

4. A system according to any one of the
preceding claims wherein said vessel has an
axis of symmetry and wherein said tanks are
disposed symmetrically in spaced-apart pairs
on opposite sides of said axis.

5. A system according to claim 4 wherein
said conduit means comprises a respective air
passageway between each of said pairs of
tanks.

6. A system according to claim 5 wherein
said passageway includes a continuous open
120 pipe.

7. A system according to any one of the
preceding claims wherein said means for selec-
tively pressurizing said tanks provides adjust-
able air pressure therein to permit water to
125 completely fill one of said tanks during a por-
tion of a cycle of oscillatory motion of the
vessel for preventing capsizing of the vessel
by causing the righting moment thereof to in-

18



crease rapidly as a function of additional angular displacement of the vessel during the portion of the cycle that the tank is completely filled.

5 8. A system according to claim 7 wherein said means for providing air pressure in said tanks includes an air pump and valve means for isolating said air pump from said conduit means.

10 9. A system according to claim 2 wherein said tanks are disposed within the hull of said vessel.

15 10. A system according to claim 1 wherein said tanks are disposed on the sides of the hull of said vessel.

11. A system according to claim 10 wherein said tanks are disposed partially within the hull of said vessel.

20 12. A passive method for stabilizing a sea-going vessel having two tanks disposed on said vessel below the water line on opposite sides of an axis of symmetry of said vessel, the method comprising the steps of:

25 filling one of said tanks to a first water level in phase with the tarvel of said tank into the sea during a cycle of oscillatory vessel motion; and

30 simultaneously draining the other of said tanks to a second water level in response to the filling of said one tank during the same cycle of oscillatory vessel motion by directing air forced out of said one tank being filled into said other tank through conduit means defining a passive air passageway;

35 thereby to reduce the righting moment of said vessel and lengthen the period of oscillation of said vessel beyond the wave period of the sea.

40 13. A method according to claim 12 including pressurizing said two tanks and said conduit means with a predetermined air pressure to select said first and second water levels attained in said tanks during the filling and draining steps respectively.

45 14. A method according to either one of claims 12 and 13 including completely filling each tank upon a predetermined travel into the sea, thereby to prevent capsizing of the vessel by causing the righting moment thereof to increase rapidly as a function of additional angular displacement of the vessel when the tank is completely filled.

50 15. A method according to either one of claims 12 and 13 including completely filling each tank in response to predetermined angular displacement of the vessel about its axis of symmetry to rapidly increase the righting moment thereof as a function of additional angular displacement and prevent capsizing of the vessel when the tank is completely filled.

60 16. In a vessel having an axis of symmetry a passive system for stabilizing the vessel comprising:

65 a plurality of tanks disposed on said vessel in spaced apart pairs on opposite sides of said

axis and below the water line, each of said tanks having a bottom portion substantially completely open to the sea and being dimensioned to fill and drain in phase with oscillatory vessel motion relative to the surface of the sea during each cycle of said oscillatory motion;

70 conduit means coupled to the top surfaces of said tanks for providing separate passive air passageways between each of said pairs of tanks, and said conduit means including a continuous open pipe interconnecting each of said pairs of tanks;

75 means coupled to said conduit means for providing a selected air pressure in said tanks and said conduit means to permit selected water levels to be attained in said tanks during oscillatory motion of said vessel, thereby to reduce the righting moment of said vessel and lengthen the period of oscillation of said vessel beyond the wave period of the sea.

80 17. A system according to claim 16 wherein said tanks are disposed on the bottom of said vessel.

85 18. A system according to either one of claims 16 and 17 wherein the tank height dimension of each of said tanks is selected to permit complete filling and draining of each tank during a portion of a cycle of oscillatory motion of the vessel, thereby to prevent capsizing of the vessel by causing the righting moment thereof to increase rapidly as a function of additional angular displacement of the vessel during the portion of the cycle that one of said tanks is completely filled.

90 19. A system according to any one of claims 16 to 18 wherein said means for providing air pressure in said tanks is adjustable to permit water to completely fill the tanks on one side of said axis during a portion of a cycle of the oscillatory motion of said vessel.

95 20. A system according to claim 16 wherein said means for providing air pressure in said tanks includes an air pump and valve means for isolating said air pump from said conduit means.

100 21. A system according to any one of claims 16 to 20 wherein each of said tanks is disposed on the hull of the vessel with at least a portion of the tank positioned outside the contour of the hull.

105 22. A system according to claim 21 wherein said tanks are positioned entirely outside the contour of the hull of the vessel.

110 23. A system according to either one of claims 18 and 19 wherein each completely filled tank is a tank on the side of the axis of symmetry of the vessel toward which the vessel is heeling.

115 24. A method according to anyone of claims 12-15 wherein the steps of filling and simultaneously draining are both effected continuously.

120 25. A passive method for stabilizing a sea-going vessel having two tanks disposed on said

70

75

80

85

90

95

100

105

110

115

120

125

130



7

1,603,224

7

vessel below the waterline on opposite sides of an axis of symmetry of said vessel, substantially as hereinbefore described with reference to the accompanying drawings.

ing vessel substantially as hereinbefore described with reference to the accompanying drawings.

5 26. A passive system for stabilizing a float-

SEATEK CORPORATION.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1981.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from
which copies may be obtained.