Oct. 7, 1941.

L. F. MOODY

2,258,464

HYDRAULIC OSCILLATOR

Filed March 29, 1938

4 Sheets-Sheet 1

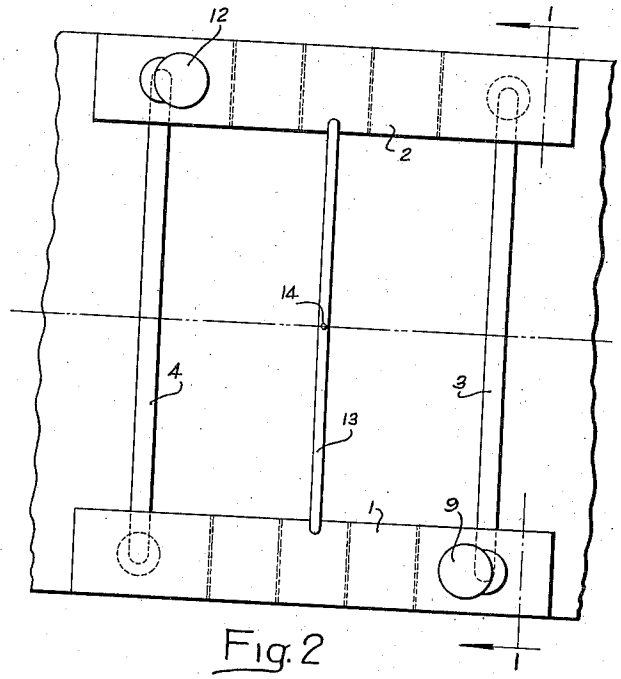


Fig. 2

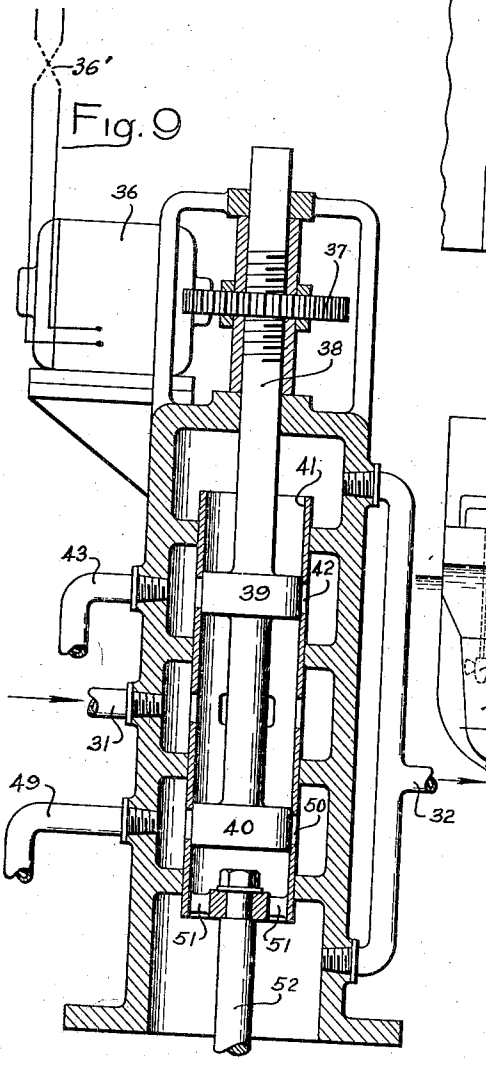


Fig. 9

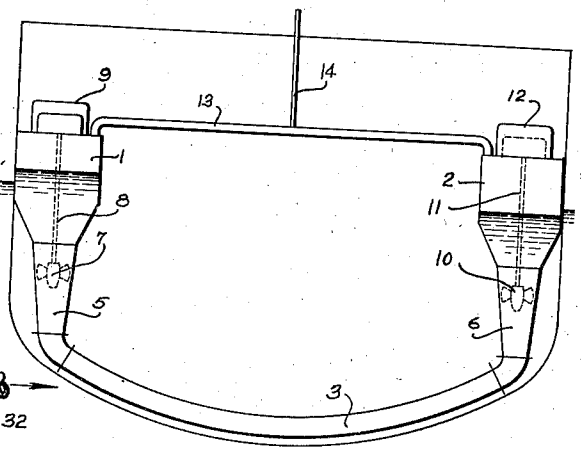


Fig. 1

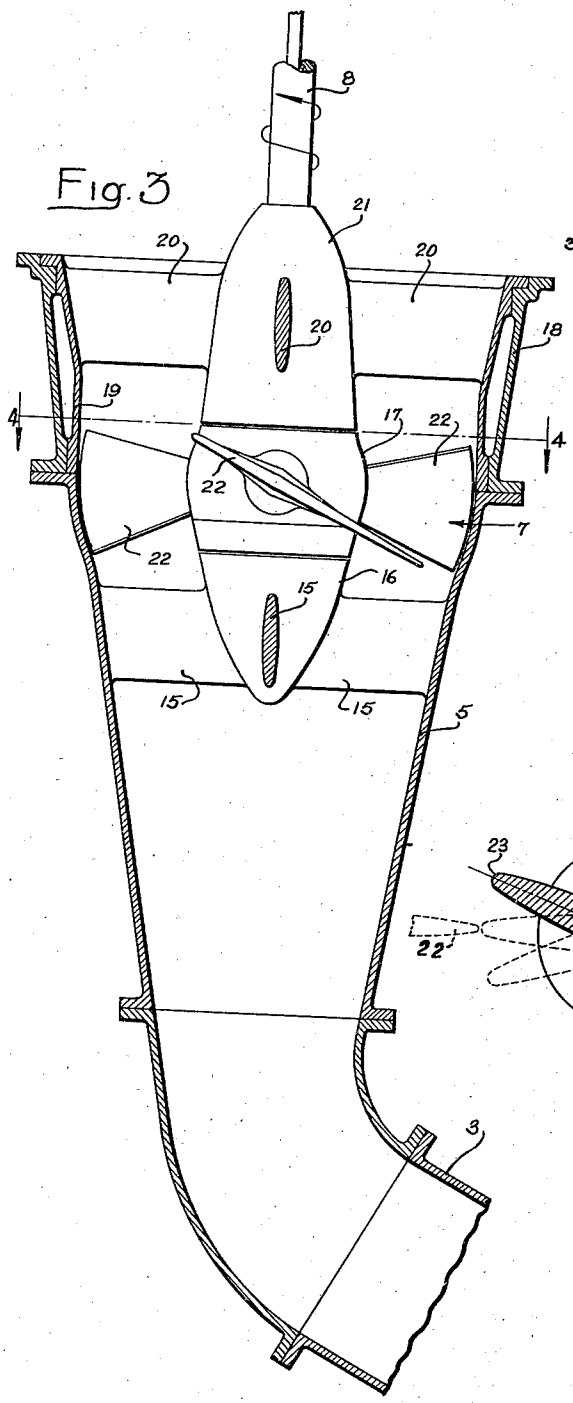
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Oct. 7, 1941. L. F. MOODY 2,258,464

HYDRAULIC OSCILLATOR

Filed March 29, 1938 4 Sheets-Sheet 2

Fig. 3



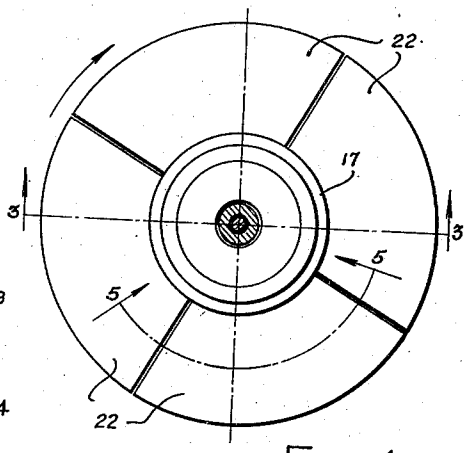


Fig. 4

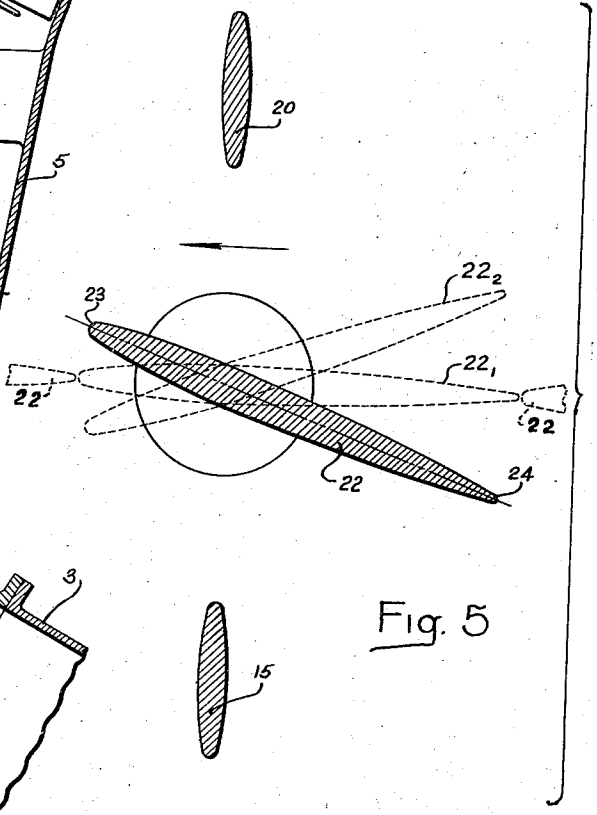


Fig. 5

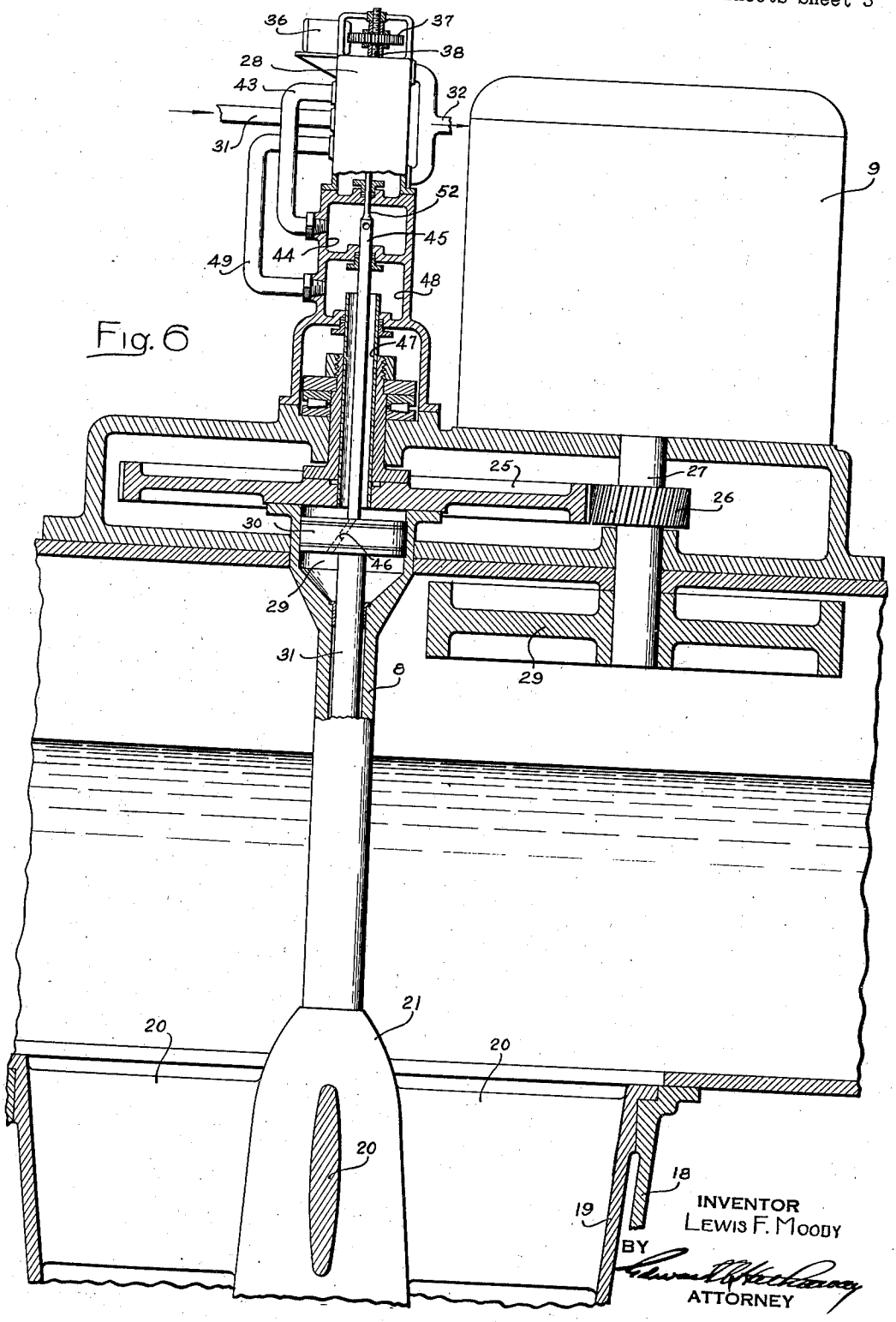
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HYDRAULIC OSCILLATOR

Filed March 29, 1938 4 Sheets-Sheet 3

Fig. 6



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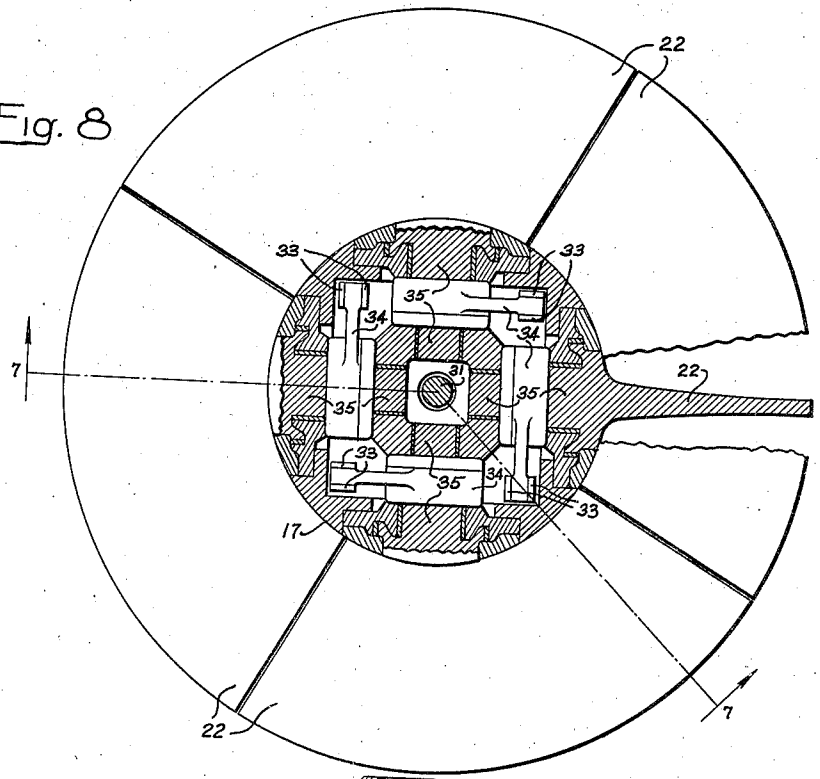
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Oct. 7, 1941. L. F. MOODY 2,258,464

HYDRAULIC OSCILLATOR

Filed March 29, 1938 4 Sheets-Sheet 4

Fig. 8



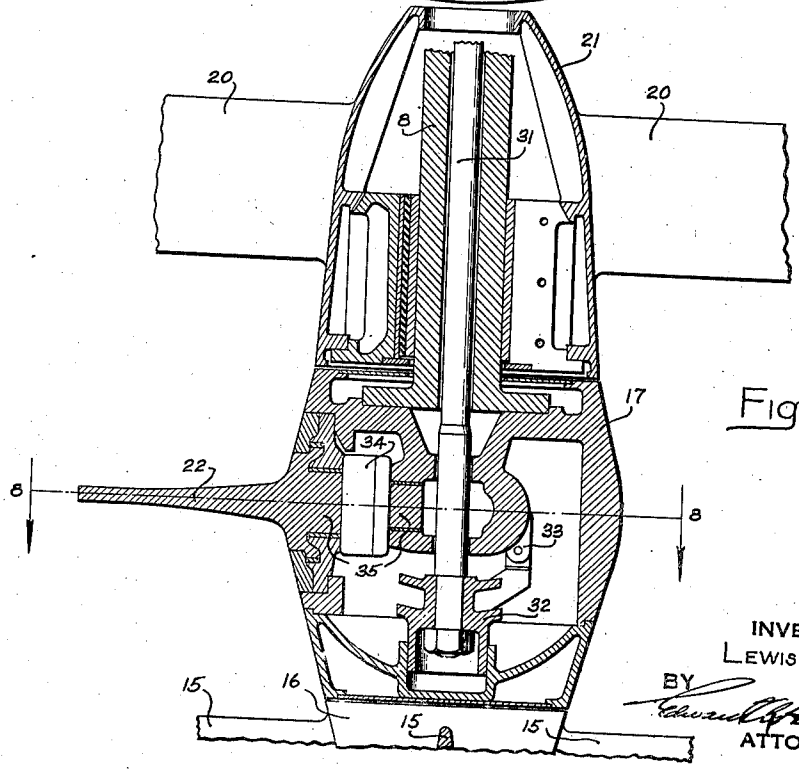


Fig. 7

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Patented Oct. 7, 1941 2,258,464

UNITED STATES PATENT OFFICE

2,258,464

HYDRAULIC OSCILLATOR

Lewis Ferry Moody, Princeton, N. J.

Application March 29, 1938, Serial No. 198,792

18 Claims. (Cl. 114—125)

This invention relates to a device for setting up an oscillating or reciprocating motion in a column of fluid contained in a conduit connecting two reservoirs, and maintaining this oscillating motion against opposing forces such as friction or fluid resistances and any external force tending to oppose the oscillation. The use of the device is illustrated in connection with a system of ship stabilization, or anti-rolling installation. Another possible application is the use of two of the devices such as described for the hydraulic transmission of power.

The device cannot be properly termed either a pump or a turbine, since its purpose and function are definitely differentiated from either. A pump delivers fluid in a single direction against a continuously opposing head, and its operation results in the delivery of fluid which never again passes through the machine; that is, there is a net quantity of fluid transferred from a sump to a point of delivery, at the expense of a continuous expenditure of power. In a turbine, fluid is passed in a single direction, under head, through the machine, with a net transfer of fluid from a reservoir to a tail-race, and with continuous delivery of power to a driven machine. The present device, in contrast, entails no net quantity of fluid either pumped or allowed to pass in one direction of flow; all the fluid passing in one direction subsequently flows back in the opposite direction in a cyclic action continuously recurring, and there is an alternating expenditure and delivery of power from and by the hydraulic portion of the device to or from the electric generator-motor to which it is connected. While the object of a pump or turbine is the continuous delivery of fluid against a head or utilization of a flow of fluid under head, in this invention the "head" produced by the machine, at certain points in the cycle of operation, is an "acceleration head" imparted to the flow to accelerate its velocity; and at other points of the cycle a "deceleration head," tending to cause a certain rate of retardation of the fluid flow, is abstracted from the fluid energy. The amount of this acceleration head is expressed mathematically by

$$\frac{L}{g}\frac{dv}{dt}$$

in which L is the equivalent length of the conduit, g the acceleration of gravity, and

$$\frac{dv}{dt}$$

is the derivative of the equivalent velocity of flow with respect to time. The purposes and mode of operation will be best understood from the following description of specific applications, as illustrated in the following figures:

Fig. 1 is a diagrammatic sketch representing a cross-section, on line 1—1 of Fig. 2, of a ship, illustrating the use of the invention in a ship-stabilizing system;

Fig. 2 is a diagrammatic sketch representing a plan view of a portion of the ship of Fig. 1;

Fig. 3 is a section of the hydraulic oscillator unit, on line 3—3 of Fig. 4, showing the hydraulic portion of the device, in a meridian plane, or plane containing the axis of rotation;

Fig. 4 is a transverse section of the oscillator in plane 4—4 of Fig. 3, being a view looking down on the runner or revolving hydraulic element;

Fig. 5 is an enlarged cylindrical section on line 5—5 of Fig. 4, developed, or unrolled on a plane, showing the relation and formation of the fixed vanes and rotating blades;

Fig. 6 is a continuation, to a somewhat larger scale, of Fig. 3, showing the upper portion of the oscillator device, including the upper fixed vanes, the power shaft, blade operating cylinder, control valve, reduction gears and electric generator-motor;

Fig. 7 is an enlarged view of the runner in meridian section, or section containing the axis of rotation, along lines 7—7 of Fig. 8, showing the blade-adjusting mechanism within the hub;

Fig. 8 is a transverse section through the runner hub on line 8—8 of Fig. 7;

Fig. 9 is an enlarged section of the control-valve, the details of which were omitted in Fig. 6.

Before describing the oscillator unit itself, its application to ship stabilization will first be explained. Referring to Figs. 1 and 2, 1 and 2 are ballast tanks or bilge tanks located at each side of the ship at or near the midship section, connected by the cross-pipes 3 and 4 along the bottom of the ship. These cross-pipes are connected to the tanks by the vertical pipes or casings 5 and 6, preferably of gradually tapering form as shown.

Within the pipe or casing 5 is the revolving runner 7 of a hydraulic oscillator, shown dotted, connected by a vertical power shaft 8 to a reduction gear and electric generator-motor 9 mounted on top of tank 1. On the right-hand side of Fig. 1, 10 indicates in dotted lines the runner of a second hydraulic oscillator, with its shaft 11 and generator-motor 12. These are behind the plane of Fig. 1, and runner 10 is not within the vertical section of pipe 3, but within the corresponding section of pipe 4, the generator-motor being lo-

cated at 12 in Fig. 2. Thus each cross-pipe such as 3 and 4 has one oscillator unit at one side, that for pipe 3 being at 9 and the one for pipe 4 being at 12, in Fig. 2. By thus "staggering" or alternating the units, the weights on both sides of the ship are equalized. Other pairs of units similarly arranged can be added along the length of the ship to give the desired stabilizing capacity. When unit 7—9 is accelerating the fluid column in pipe 3 by impelling it downward, unit 10—12 is accelerating the fluid in pipe 4 by drawing it upward, so that the two columns swing in unison, and similarly when the flow is reversed.

It will be seen from the disclosure herein that the oscillator unit is not symmetrical about a horizontal plane through its runner, since in downward flow the fluid is passing from a tank in which the velocity is low through a generally contracting passage into a pipe of smaller section and increased velocity of flow, while for upward flow the fluid passes through the reverse process in a generally enlarging passage. Any resulting lack of perfect hydraulic symmetry between upward and downward flow is compensated by arranging the oscillators in pairs, each pair having one unit on each side of the ship and each acting separately within its own conduit. The conduits extending from one tank to the other are laterally enclosed, that is the conduits are open only at their ends where they communicate with the tanks. The conduits are otherwise entirely closed around their circumference from one tank to the other so that fluid is compelled to flow from one tank to the other.

The fluid in the tanks and pipes may be fresh or sea-water or fuel oil. The action will be described for water, but will be similar with oil but with greater hydraulic resistances due to viscosity. The tank on each side is common to a series of units, and each tank can be equipped with swash plates to limit fore and aft surging within the tank during severe pitching of the vessel. Small pipes 13 running athwartship to interconnect the air spaces in the tanks allow for a displacement of air to avoid compressing the air in the tanks, and a riser pipe as at 14 may be added to maintain the air pressure at substantially atmospheric value.

Fig. 3 is a cross-section through the axis of one of the oscillator units such as 5—9 of Figs. 1 and 2, the runner denoted generally by 7 being shown solid with the front half of the casing removed. 5 denotes the tapering pipe connecting to cross-pipe 3. Within the tapering section is a series of axially directed fixed guide and stay vanes 15 carrying a central fixed cone 16 continuous in contour with the rotating runner hub 17. Above the runner the casing 18 contains a removable liner 19 forming a continuation of the taper pipe and carrying a second series of axially directed fixed guide and stay vanes 20. These vanes carry the bearing housing 21, continuous in contour with the runner hub. Between the runner blades and each set of fixed vanes 15 and 20 is a transmission space in which the flow merges into a continuous ring of fluid. The casing 18 is bolted to the bottom of the tank 1. The runner hub is attached to the power shaft 8. When desired a stub shaft extension may be added below the runner hub, running in a steady bearing within the cone 16, to give additional lateral support for the revolving element. This is not shown, as its addition can be readily understood without illustration. The liner and bearing housing 19—21 would be made in halves bolted together, to permit removal from the shaft; or if preferred the shaft could connect to the runner hub by a taper fit, to permit its withdrawal.

Fig. 4 is a plan view, looking down on the runner. The runner consists of the hub 17 carrying the blades 22 which are pivotally supported by it, and capable of angular movement relatively to the hub. The blade operating mechanism is carried within the hub and shaft, as shown in detail in Figs. 7 and 8.

Fig. 5 is a cylindrical section along line 5—5 of Fig. 4, unrolled or developed into a plane. It shows the relation between the runner blades 22 and the fixed guide vanes 15 and 20. The direction of motion of the shaft and runner is indicated by the arrows around shaft 8 in Fig. 3, at the runner periphery in Fig. 4 and just above blade 22 in Fig. 5. Since the fluid flow alternates between upward and downward, the guide vanes 15 and 20 are symmetrical in section about a vertical central plane, to direct the flow into the runner or away from the runner in an axial direction; and the sections are also symmetrical about a horizontal plane to give equally good flow conditions for upward and downward flow. They are thickest in the middle, tapering to rounded edges of small thickness at both ends, with smooth flow contours.

The runner blades 22 are symmetrical in section about a plane surface, the entire blade being symmetrical about a single central plane extending from hub to periphery. This is an essential condition since the runner is desired to operate with equal effect when the flow is upward and when it is downward. It is a feature of this invention that the runner shall operate in a single and unvarying direction of rotation, thus not requiring a direction-reversing electrical generator-motor. This uni-directional rotation results in one edge 23 of the runner blade being always the entrance edge where the blade enters the flow, and the other edge 24 always being the leaving edge. To suit this uni-directional flow along the blade, the section is made thickest near the entrance edge, with well rounded entrance, and is tapered gradually to a thin leaving edge to minimize the production of an eddying wake.

The runner blade is rotated with angular reciprocating motion relatively to the hub into the angular positions shown in dotted lines through an angular range from 22 to 22_2, this reciprocation being continuously maintained. In mid-position, 22_1, the central planes of all the blades come into a single plane normal to the axis of rotation; and each blade in plan view as in Fig. 4 is a sector, so that all the blades together completely close the annular flow passage except for the clearance provided between adjacent blade edges, between the outer periphery and the pipe or casing wall, and between the inner blade periphery and the hub, these clearances being sufficient to avoid fouling or rubbing between blades, and between blades and pipe wall. In mid-position 22_1, the blades thus effectively close the passage against any substantial flow, and in effect act as a shut-off valve. By this means a safety feature is provided so that if at any time due to a failure or improper functioning of the electrical controls, the burning out of the generator-motor or other accidental cause the fluid column oscillation should reverse its proper phase in relation to the rolling of the ship, so that it would then tend to build up the rolling, or if continued to endanger overturning, an auxiliary control

such as a push-button circuit or hand switch 35' can be provided to throw the blades into mid-position and to lock the fluid in the tanks. If unequally divided between the two tanks a slight list would be imparted to the ship until the balance is corrected, but no augmentation of roll would ensue.

The functioning of the system for ship stabilizing may be explained by comparing the motion of the fluid column in the cross-pipes to that of a pendulum bob. The effect is roughly like that of shifting ballast to oppose the rolling of the ship. If the fluid in the pipes and tanks is once set into oscillation in synchronism with, and in opposite direction to, the rolling of the ship, it is possible by proper proportioning for the fluid oscillation to maintain itself, taking energy from the rolling energy of the ship to overcome the fluid resistances, and automatically reducing the rolling to a small amount. This is the so-called "passive" system. Even with that method functioning properly, however, it is necessary to impose some control, to keep the oscillation in step and proper phase relations with the roll. One method employed is the use of air compressors to vary the air pressure in the tanks but this affords only slow correction and is far from positive or fully controlled.

In the system used in this invention it is possible to build up quickly by the use of the oscillator units any required degree of oscillation and to maintain it in proper phase through an electrical control system such as developed by N. Minorsky and described for example, in his Patent 2,017,072, the controls being responsive to the motion of the ship. With erratic rolling in a disturbed sea the fluid column oscillation can be quickly regulated, and the rolling of the ship can be confined to a small amplitude.

The method of quickly creating and quickly controlling the oscillation demanded by the degree and kind of rolling experienced by the ship at any time is the use of the oscillator units here described. Comparing the motion of the fluid column to that of a pendulum bob, the pendulum on its forward swing is pulled down by gravity which at first accelerates its velocity on the downswing, then retards it on the upswing. The action of the hydraulic oscillator is somewhat similar to that of gravity in that when the fluid is higher than normal in one tank and tends to flow through the cross-pipe into the other tank under the acceleration of gravity, the oscillator runner has its blades turned so that it tends to impel the flow downward and to add an additional acceleration, tending to speed up the downward flow, taking power from the electric driving unit which is then acting as a motor, and delivering head, effective as acceleration head, to the fluid. When the fluid column has been speeded up to its maximum velocity (corresponding to the bottom or middle of the pendulum swing) the runner blades are in their widest open position such as 22, Fig. 5, and are then merely threading through the flow without imparting any head. Then as the fluid begins to accumulate in the opposite tank the oscillator runner contributes a deceleration to that due to gravity, and abstracts head from the fluid motion, delivering power to the electric driving unit which now acts as a generator.

In the meantime the blades have been closing, and when the fluid reaches its highest level in the second tank (the top of the pendulum swing) the blades are in mid-position 22_1. They continue their angular movement and begin to impel the fluid upward on its return swing until it again reaches its maximum velocity, when the blades reach their greatest angle at 22_2 in the opposite direction. They then again begin to decelerate the flow until they reach the closed position 22_1 when the column is momentarily at rest, at its highest level in the first tank. The above cycle is then repeated continuously.

The change of level in the tanks, the flow velocity, and the angular motion of the blades are all substantially simple harmonic motions such as that of a pendulum, and can be represented by sine curves. The hydraulic oscillator in its complete cycle accelerates the flow in the downward direction and then retards it; then accelerates it in the upward direction and finally retards this motion. To do this the blades have turned on the hub from 22_1 to 22, back through 22_1 to 22_2, and finally return to the starting point 22_1 completing the cycle, which then repeats itself continuously.

Fig. 6 is a continuation of Fig. 3, to a slightly larger scale, showing the upper portion of the oscillator unit. The reference numerals 18 to 24 identify the parts shown in Fig. 3 which are here repeated. The power shaft 8 which drives or is driven by the runner at different parts of the cycle, is connected to the reduction gear 25 which engages the pinion 26 carried by the shaft 27 of the electric generator-motor 9. This generator-motor could be directly connected to the shaft 8 if preferred, but is here gear-connected so that it can run at a higher speed with corresponding saving in weight and size, an arrangement which simplifies the connection of control valve 28, which would otherwise have to be mounted above the generator-motor. The electrical unit is termed a generator-motor because at two points in the cycle of operation it acts as a motor supplying power to the shaft, and at two intervening points it acts as a generator taking power from the shaft; it runs continuously in one direction, however, at nearly constant speed. It may be a direct current, synchronous or induction machine. The motor shaft 27 carries a flywheel 29 advantageously mounted on this high-speed shaft rather than on shaft 8, which stores energy from the oscillator and returns energy during each cycle and thus reduces the speed variation and fluctuation of electric current. That part of the power required to drive the runner when accelerating the fluid flow which has to be supplied to the electric machine, over and above the energy supplied by the stored energy in the flywheel, is taken from the electric supply system to which the unit is connected; and at times when the runner is retarding the flow, the regenerated power left over after the flywheel absorbs its store is fed back into the line as regenerated power. Naturally more power must be taken from the line than is returned to it, to supply the hydraulic, mechanical and electrical losses in the unit and in the cross-piping and tanks. However, the so-called "passive" action of the water column during rolling of the ship tends automatically to maintain the oscillation as previously explained; only that additional amount of power required to build up the oscillation quickly and to correct erratic rolling is necessary for the continued driving of the hydraulic oscillator.

The valve 28 controls the admission and discharge of oil under pressure to or from the

operating cylinder 29. This cylinder is formed as an enlargement of the hollow shaft 8, and contains the piston 30 connected to the operating rod 31, which it moves upward and downward within shaft 8 and thereby drives the blade operating mechanism within the runner hub. This operating cylinder and blade operating mechanism is generally similar to that used in Kaplan or other adjustable-blade turbines.

The oil pressure for the blade movement is obtained from a small pump and accumulator tank, not shown, supplying oil under pressure to the valve 28 through pipe 31, the exhaust from the valve being returned to the pump through pipe 32.

The blade operating mechanism is shown in Figs. 7 and 8, which should make the mode of operation clear without detailed explanation. The operating rod 31 carries a spider 32 connected by links 33 to the cranks 34 keyed to the blade stems 35, so that a vertical movement of rod 31 causes an angular movement of the runner blades 22. While the mechanism is generally similar to that used in adjustable-blade turbines, its purpose and mode of operation are different. In the turbine the blades are adjusted intermittently in varying amounts in response to load or speed changes on the unit, for the purpose of keeping the power and discharge constant at any given load. If the power demand is steady, the mechanism remains at rest. In the oscillator unit, however, the blades are maintained in a continuous cyclic oscillating motion in order to substitute for steady flow a continuous oscillating motion of the fluid column, as described. Hence the piston 30 and the operating rod 31 are given a continuous reciprocating motion somewhat similar to that of the piston and rod of a reciprocating steam engine. The surging or oscillation of the water column hereby created is the thing which the turbine control mechanism is intended to avoid.

This motion is imparted by external electrical controls; responsive to the rolling motion of the ship. The method of operation of electrical control system regulating the current supplied to motor 36, is not a part of this invention. This currents acts on the small electric motor 36, Fig. 9, which through worm and gear 37 raises and lowers the threaded valve stem 38. This stem actuates the balanced piston valve 39, 40 sliding within the floating sleeve 41. When the stem 38 is raised, valve 39 uncovers port 42, admitting pressure oil to pipe 43 and chamber 44, from which it passes through the hollow tube 45 and passage 46 to the cylinder space below the piston 30, pushing the piston upward. The oil above the piston 30 passes through the annular space 47 into chamber 48, from which it is exhausted through pipe 49, port 50 and passages 51 to the exhaust pipe 32. Downward motion is similarly effected.

The valve contains a restoring mechanism, operating as follows: When the piston 30 moves upward as described, it pushes with it the tube 45 and the rod 52 connected to the sleeve 41, which is thereby raised in unison with the piston 30. After an initial piston movement, this movement of the sleeve causes it to overtake the valve 39, 40 and to close the ports, stopping further movement of the piston until there is another movement of the control motor 36 and valve rod 38. The action is such that the piston 30 copies the movement of control motor 36 and valve rod 38; and consequently the runner blades follow closely the dictates of the electrical controls without overtravel, moving only when the control motor moves, and to a corresponding extent.

It will of course be understood that various changes in details of construction and arrangement of parts may be made by those skilled in the art without departing from the spirit of the invention as set forth in the appended claims.

I desire to claim:

1. A hydraulic oscillator for creating, maintaining or controlling an oscillating motion in a column of fluid of a stabilizing system comprising, in combination, a uni-directional rotating shaft having a runner provided with a hub and a set of angularly oscillatable blades pivotally mounted in said hub, a set of fixed axially directed guide vanes on each side of said runner, each of said guide vanes being axially straight throughout its length, power means adapted to operate at times to drive said shaft and at other times to be driven by said shaft for either direction of flow, and means for angularly oscillating the blades of said runner through an angular range extending to each side of a transverse plane normal to the runner axis whereby the blades are adapted for continuously reversing the direction of flow through the oscillator during said uni-directional rotation.

2. The combination set forth in claim 1 further characterized in that said power means includes an electric motor and a flywheel.

3. A hydraulic oscillator for creating, maintaining or controlling an oscillating motion in a column of fluid for a stabilizing system comprising, in combination, a uni-directional rotating shaft having a runner provided with a hub and a set of angularly oscillatable blades pivotally mounted in said hub, a set of fixed axially directed guide vanes on each side of said runner, each of said guide vanes being axially straight throughout its length, power means adapted to operate at times to drive said shaft and at other times to be driven by said shaft for either direction of flow, and means for angularly oscillating the blades of said runner through an angular range substantially equally divided by a transverse plane normal to the runner axis, each of said runner blades being symmetrically formed with respect to a central surface which is a plane; and each of said fixed guide vanes being symmetrically formed with respect to a plane containing the runner axis, and symmetrically tapered to be equally adapted for flow in opposite direction.

4. A hydraulic oscillator for creating, maintaining or controlling an oscillating motion in a column of fluid for a stabilizing system comprising, in combination, a uni-directional rotating shaft having a runner provided with a hub and a set of angularly oscillatable blades pivotally mounted in said hub, a set of fixed axially directed guide vanes on each side of said runner, each of said guide vanes being axially straight throughout its length, power means adapted to operate at times to drive said shaft and at other times to be driven by said shaft for either direction of flow, and means for angularly oscillating the blades of said runner through an angular range substantially equally divided by a transverse plane normal to the runner axis, each of said runner blades being symmetrically formed with respect to a central surface which is a plane and formed in section for uni-directional flow relatively to the blade by being relatively thick near the entrance edge and gradually tapered to

a thin leaving edge; and each of said fixed guide vanes being symmetrically formed with respect to a plane containing the runner axis, and symmetrically tapered to be equally adapted for flow in opposite directions.

5. A hydraulic oscillator for creating, maintaining or controlling an oscillating motion in a column of fluid for a stabilizing system comprising, in combination, a uni-directional rotating shaft having a runner provided with a hub and a set of angularly oscillatable blades pivotally mounted in said hub, a set of fixed axially directed guide vanes on each side of said runner, each of said guide vanes being axially straight throughout its length, power means adapted to operate at times to drive said shaft and at other times to be driven by said shaft for either direction of flow, and means for angularly oscillating the blades of said runner through an angular range substantially equally divided by a transverse plane normal to the runner axis, each of said runner blades being symmetrically formed with respect to a central surface which is a plane and formed in section for uni-directional flow relatively to the blade by being relatively thick near the entrance edge and gradually tapered to a thin leaving edge, and so mounted in the hub that the axis of oscillation is nearer to the entrance than to the leaving edge of the blade; and each of said fixed guide vanes being symmetrically formed with respect to a plane containing the runner axis, and symmetrically tapered to be equally adapted for flow in opposite directions.

6. In a ship stabilizing system, tanks disposed at each side of the ship, two laterally enclosed conduits whose minimum cross-sectional area is less than that of said tanks, each conduit comprising a cross pipe disposed below the level of said tanks and vertical pipes connecting the cross pipe to each of said tanks, two substantially identical simultaneously operable hydraulic oscillator units each comprising power means and a vertical shaft propeller-type runner adapted to be driven by or to drive said power means, the runner of one of said oscillator units being disposed in the vertical pipe of one of said conduits and the runner of the other oscillator unit being disposed in the vertical pipe of the other conduit, one of said runners being on one side of the ship and one on the other side in staggered relation to each other so as to cause alternating flow of fluid in said vertical pipes whereby the flow is upward through one runner and simultaneously downward through the other thereby causing the hydraulic characteristics of one unit to be compensated by the hydraulic characteristics of the other unit so as to obtain hydraulic symmetry during roll of the ship in either direction.

7. In a ship stabilizing system, tanks disposed at each side of the ship, two laterally enclosed conduits whose minimum cross-sectional area is less than that of said tanks, each conduit comprising a cross pipe disposed below the level of said tanks and vertical pipes connecting the cross pipe to each of said tanks, two substantially identical simultaneously operable hydraulic oscillator units each comprising power means and a vertical shaft oscillatable-blade propeller-type runner adapted to be driven by or to drive said power means, the runner of one of said oscillator units being disposed in the vertical pipe of one of said conduits and the runner of the other oscillator unit being disposed in the vertical pipe of the other conduit, one of said runners being on one side of the ship and one on the other side in staggered relation to each other so as to cause alternating flow of fluid in said vertical pipes whereby the flow is upward through one runner and simultaneously downward through the other, thereby causing the hydraulic characteristics of one unit to be compensated by the hydraulic characteristics of the other unit so as to obtain hydraulic symmetry during roll of the ship in either direction.

8. In a ship stabilizing system, tanks disposed at each side of the ship, two laterally enclosed conduits whose minimum cross-sectional area is less than that of said tanks, each conduit comprising a cross pipe disposed below the level of said tanks and vertical pipes connecting the cross pipe to each of said tanks, two substantially identical simultaneously operable hydraulic oscillator units each comprising power means and a vertical shaft propeller-type runner adapted to be driven by or to drive said power means, the runner of one of said oscillator units being disposed in the vertical pipe of one of said conduits and the runner of the other oscillator unit being disposed in the vertical pipe of the other conduit, one of said runners being on one side of the ship and one on the other side in staggered relation to each other so as to cause alternating flow of fluid in said vertical pipes whereby the flow is upward through one runner and simultaneously downward through the other thereby causing the hydraulic characteristics of one unit to be compensated by the hydraulic characteristics of the other unit so as to obtain hydraulic symmetry during roll of the ship in either direction, and means providing an enclosed air space above the liquid in said tanks and a pipe interconnecting the air spaces.

9. A hydraulic machine for a stabilizing system comprising two series of fixed guide vanes, an unshrouded axial-flow runner disposed between said series of fixed vanes and separated therefrom by transition spaces, each of said guide vanes being axially straight throughout its length and formed symmetrically with respect to planes containing the axis of runner rotation and equally adapted to direct the flow axially in either direction whereby the fluid flows only along axially straight lines, said runner having a hub provided with journal bearings and runner blades having shafts journalled in said bearings to allow oscillation of said blades, said blades being formed symmetrically with respect to a central plane surface, and means for angularly oscillating said blades through substantially equal angles to either side of a plane normal to the runner axis.

10. A hydraulic machine for a stabilizing system comprising two series of fixed guide vanes, an unshrouded axial-flow runner including blades between said series of fixed vanes and separated therefrom by transition spaces, each of said guide vanes being axially directed throughout its length and formed symmetrically with respect to planes containing the axis of runner rotation and equally adapted to direct the flow axially in either direction, said runner having a shaft and a hub supported thereon, journal bearings in said hub for rotatably supporting said runner blades therein, means for angularly oscillating said blades through substantially equal angles to either side of a plane normal to the runner axis, said blade oscillating means including a piston and cylinder rotating with said runner shaft, a valve for controlling the admission of pressure fluid to said cylinder, electrical means for actu-

ating said valve, and a restoring connection from said piston to said valve.

11. A hydraulic machine for a stabilizing system comprising two series of fixed guide vanes, an unshrouded axial-flow runner including blades between said series of fixed vanes and separated therefrom by transition spaces, each of said guide vanes being axially directed throughout its length and formed symmetrically with respect to planes containing the axis of runner rotation and equally adapted to direct the flow axially in either direction, a shaft, a hub mounted on said shaft, journal bearings in said hub for rotatably supporting said runner blades, means for angularly oscillating said blades through substantially equal angles to either side of a plane normal to the runner axis, said blade oscillating means including a piston and cylinder rotating with said runner shaft, cooperating valve and ported elements for controlling the admission of pressure fluid to said cylinder, movable electrical means for actuating one of said elements, and a restoring connection from said piston to the other of said elements for causing said piston to follow the electrically moved element, the effective port opening of said ported element being produced by a differential motion between the actual movement of said electrical means and the movement of said piston.

12. A hydraulic machine for ship stabilization comprising two series of fixed guide vanes, an unshrouded axial-flow runner between said series of fixed vanes and separated therefrom by transition spaces, each of said guide vanes being axially directed throughout its length and formed symmetrically with respect to planes containing the axis of runner rotation and equally adapted to direct the flow axially in either direction, said runner having a shaft and a hub secured thereto, runner blades, journal bearings in said hub for rotatably supporting said runner blades, means for angularly oscillating said blades through substantially equal angles to either side of a plane normal to the runner axis whereby the machine acts at times as a pump in either direction of flow and at other times as a turbine in either direction of flow, said blade oscillating means including a piston and cylinder rotating with the runner shaft, a valve for controlling the admission of pressure fluid to said cylinder, an electrical motor for reversely actuating said valve, and a restoring connection from said piston to said valve.

13. A hydraulic machine for a stabilizing system comprising two series of fixed guide vanes, an unshrouded axial-flow runner between said series of fixed vanes and separated therefrom by transition spaces, said guide vanes being formed symmetrically with respect to planes containing the axis of runner rotation and equally adapted to direct the flow axially in either direction, said runner including a hub having journal bearings and blades rotatably supported in said bearings, a shaft upon which said hub is mounted, means for angularly oscillating said blades through substantially equal angles to either side of a plane normal to the runner axis, said blade oscillating means including a piston and cylinder rotatable with said runner shaft, mechanism for controlling operation of said oscillating means including a valve and a ported floating sleeve cooperating with said valve for controlling admission of pressure fluid to said cylinder, electrical actuating means for moving said valve to effect operation of said piston and thereby adjust said runner blades, and a restoring connection from said piston to said floating sleeve for causing said piston to follow the valve movement.

14. A hydraulic machine for a stabilizing system comprising two series of fixed guide vanes, an unshrouded axial-flow runner including blades between said series of fixed vanes and separated therefrom by transition spaces, each of said guide vanes being formed symmetrically with respect to planes containing the axis of runner rotation and equally adapted to direct the flow axially in either direction, and each of said runner blades being formed symmetrically with respect to a central plane surface, said runner having a hub, journal bearings in said hub for rotatably supporting said blades therein, and means for angularly oscillating said blades from one side to the other of a plane normal to the runner axis so that said machine functions at one time as a pump in either direction of flow and at another time as a turbine in either direction of flow.

15. A hydraulic machine for a stabilizing system comprising two series of fixed guide vanes, an unshrouded axial-flow runner including blades between said series of fixed vanes and separated therefrom by transition spaces, each of said guide vanes being formed symmetrically with respect to planes containing the axis of runner rotation and equally adapted to direct the flow axially in either direction, and each of said runner blades being formed symmetrically with respect to a central plane surface, said runner having a hub, journal bearings in said hub for rotatably supporting said blades, means forming a flow passage in which said runner is disposed, means for angularly oscillating said blades from one side to the other of a plane normal to the runner axis, said runner blades being formed symmetrically with respect to a central plane surface whereby said blades when turned into a plane normal to the runner axis substantially fill the transverse area of the flow passage occupied by said runner so that in that position the blades are adapted to constitute a stop valve substantially preventing flow.

16. A hydraulic oscillator for creating, maintaining or controlling an oscillating motion in a column of fluid of a stabilizing system, comprising, in combination, a runner and shaft therefor having uni-directional rotation, a set of angularly oscillatable blades pivotally mounted in said runner, a set of fixed axially directed guide vanes on each side of said runner, each of said guide vanes being axially straight throughout its length, power means adapted to drive said shaft and at other times to be driven by said shaft for either direction of flow in a continually recurring cycle, and means for angularly oscillating the blades of said runner from one side to the other of a transverse plane normal to the runner axis.

17. In a ship stabilizing system, two tanks located respectively at each side of the ship, a cross pipe disposed below the level of said tanks, vertical conduits connecting said cross pipe to each of said tanks, and a single hydraulic oscillator unit comprising power means and a vertical shaft oscillatable blade propeller-type runner located in one of said vertical conduits to be driven by or for driving said power means so as to be adapted to cause an alternating flow of fluid in said cross pipe.

18. In a ship stabilizing system, two tanks with one disposed at each side of the ship, two cross pipes disposed below the level of said tanks, verti-

cal conduits connecting said cross pipes to said tanks and two substantially identical hydraulic oscillator units each comprising power means and a vertical shaft propeller type runner adapted to be driven by or to drive said power means and to cause alternative fluid flow between said tanks, said oscillator units being respectively located adjacent each tank and arranged in staggered relation by having one of the units disposed in one of said vertical conduits and the other disposed in the other vertical conduit, the portion of each conduit above its runner having a passage formation different from that below the same whereby for a given runner speed during the cycle of operations the hydraulic characteristics for upward flow through the runner will be rendered unequal to those for downward flow, the staggered relation of the oscillator units causing one oscillator to be pumping with up-flow while simultaneously the other oscillator unit is pumping with down-flow whereby said unequal hydraulic characteristics compensate for each other during roll of the ship in either direction.

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