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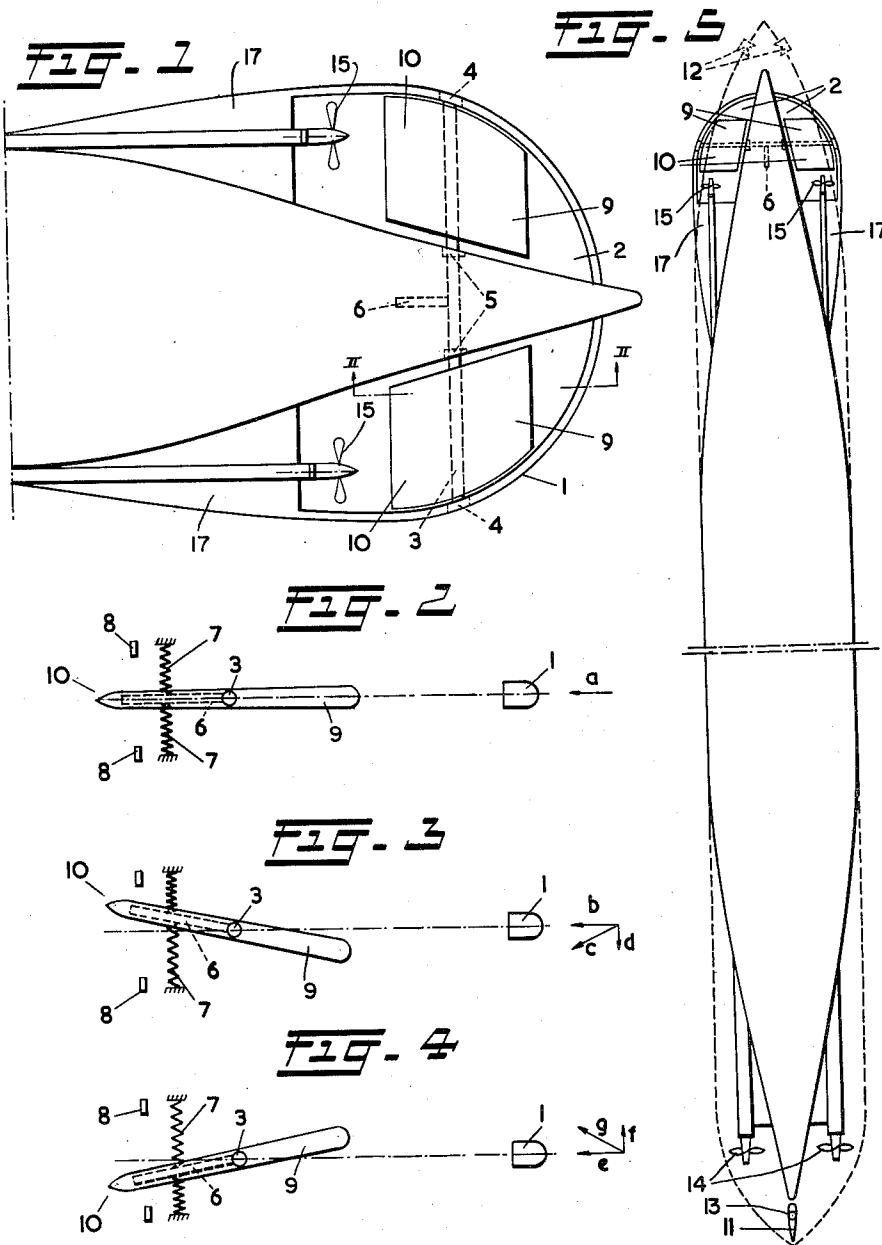
J. DE BEURS

3,018,749

ANTI-PITCH STABILIZERS FOR SHIPS

Filed June 27, 1958

2 Sheets-Sheet 1



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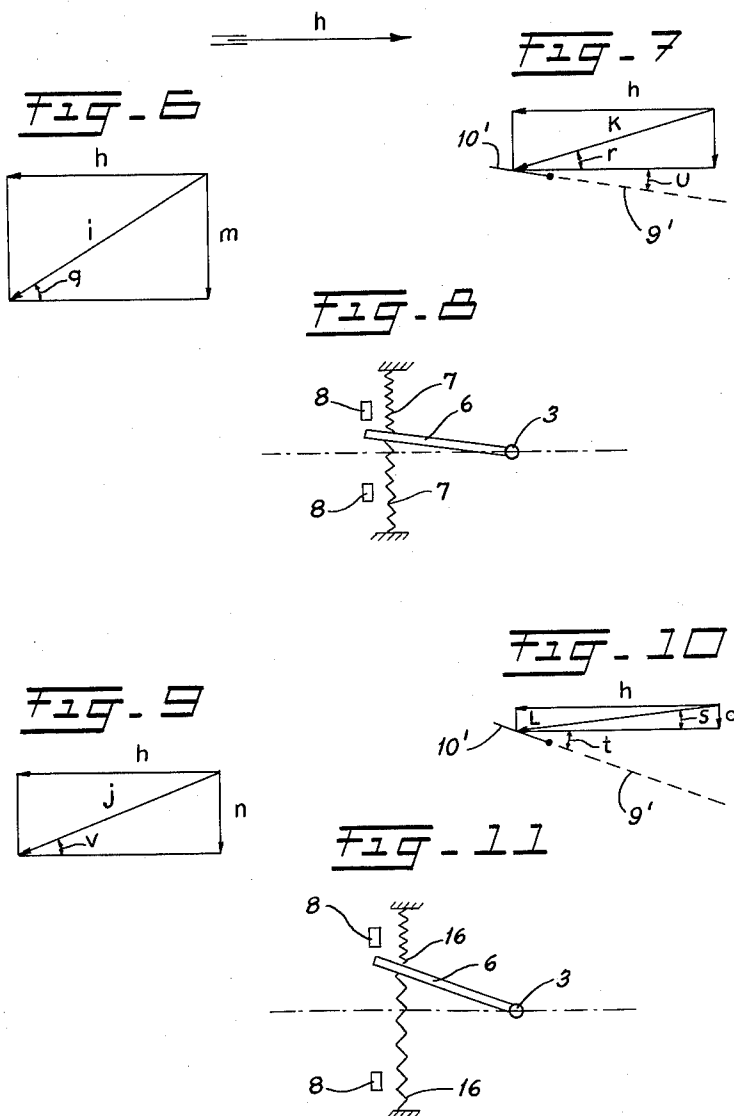
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ANTI-PITCH STABILIZERS FOR SHIPS

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2 Claims. (Cl. 114—126)

This invention relates to ships and especially to ships having bow-screws, as are known from United States patent specification No. 2,617,379.

This invention relates particularly to pitch damping mechanism for ships employing movable fins, arranged at the bow, to utilize the resistance of the water and the movements of the ship to render the movements of the fins automatic for pitch damping purposes. In roll damping equipment, motive power is required to work the fins and the known constructions for automatically damping the pitching motion show various drawbacks, which will impair their proper action and usefulness as pitch damping devices.

For instance, in one of the known constructions the balancing planes, with the axes of rotation located behind the centres of pressure, are housed in recesses which may be opened or closed by suitable means. The planes normally occupy a horizontal position, but at a predetermined small angle of inclination of the axis of the ship, the planes become free and automatically take up an extreme angular position, defined by fixed stops. Suitable mechanism is arranged so that at the moment when the inclination of the axis of the ship in either direction again reaches the set limit, the planes are forced into a horizontal position for reversing this extreme angular position.

There are serious objections against the device and basic differences with the present invention. Reversing the extreme angular position of the planes has to be a swift operation in pitch, which will cause abruptly formidable forces on the planes, i.e. the maximum quenching forces. Though hydraulic pistons and brakes are used to facilitate the operation, it is obvious that such sudden forces on the planes should be avoided by all means.

The difference between the fixed stops of said device, and the abutments which are a feature of this invention, is fundamental. The fixed stops have for their purpose to define an extreme angular position of the planes during every swing of the bow, up or down, which position is thus stationary fixed by the stops during a whole swing. The abutments, on the other hand, have no influence on the normal operation of the stabilizing fins, the so-called damper, the resiliency of the device defining the extreme stroke of the damper and thus preventing cavitation. Their purpose is to work as a safeguard in an emergency, i.e. to limit the stroke of the damper when a sudden disturbance in the seaway, which even in a regular seaway may occur, would cause cavitation.

Another known construction relates to elastically-connected unbalanced surfaces for automatically insuring the stability of airships, aeroplanes and submarine boats. However, said device does not pay any attention to cavitation, which is a major and decisive problem in damping pitch.

In said device the elastic connections between the movable planes and the moving body are conveniently disposed to counteract the action of the fluid impinging obliquely on the plane and to stop the latter in a position in which its angle of deviation is greater than the angle of deviation of the axis of the moving body.

However, this includes the danger that the angle formed by the fluid and the plane, will become too great and will cause cavitation, i.e. formation of bad local flow

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conditions, which would impair the working of the plane as a pitch damping device.

The present invention relates, generally, to a device of this known type, stating procedures and giving means to prevent cavitation in pitch under all circumstances.

Pitching is a most important problem for sea-going ships when they are running at high speeds directly against wind and waves. This is especially so in a heavy sea, i.e., when the length of the ship is the same, or about the same, as that of the waves. My considerations hereafter will be based on the assumption that there is this connection between wave- and ship-length.

A seaway formed by regular waves is composed of a system of waves in different states of generation and decay. The ultimate shape for the state of generation, in any regular seaway, is represented by the so-called significant waves with sharp-edged wave crests, which dominate the sea by their height and spectacular appearance. The significant wave is not of lasting duration but after only a short time the wave crest becomes unstable, tumbles over to leeward and the wave flattens, but a new significant wave will be generated in its rear. Though all waves contribute to the pitching motion, the significant wave is decisive as regards the seaworthiness of the ship and, therefore, is assumed here.

In a heavy sea the waves are capable of producing considerable pitching and since the accelerations of the upward and downward motion at different parts of the hull, caused by the oscillations, are proportional to the speed of the ship, any increase in speed will cause the movements to become more violent. At high speeds the ship tends to bury the bow in the waves and it will be impossible to maintain the maximum fair weather speed, either (1) because the resistance to driving becomes too great and spray and water will be shipped in large quantities or (2) because the strains on the ship become excessive. For either of these reasons or both, the ship will be forced to slow down the engines to improve the seaworthiness. This limit of speed in rough weather is often reached before the engines have developed their full power. The anti-pitch stabilizer will have for its purpose to keep ship's accelerations to a reasonable minimum so that the ship can be operated at full power of the engines even in severe sea conditions. In more easy sea conditions the greater part of the pitching motion may thus be eliminated.

A controllable hydrofoil fin, as a wave-reducing and pitch-damping device, has to accomplish two conflicting tasks. The direction of the apparent flow of water at the bow during pitch is changing continually over large angles of amplitude. The hydrofoil fin, operating under such conditions, has to maintain a large low-pressure region along the bow and, moreover, has to dampen pitch. Since for these effects quite different angles of attack are necessary, the hydrofoil fin encounters a serious drawback to solve both problems at the same time.

In comparison with the rolling motion, very great forces are involved in the pitching motion and any device to check this motion must be of large area and of great structural strength. A choice for the location between the bow and the stern has to be in favor of the bow because, except for the bow wave, undisturbed water will be met here. A horizontal plate on both sides of the bow would be the most simple solution, but its effect on the pitching could only be varied by its area and still not solve the problem. By providing horizontal fins at the bow with a common axis for rotation, a simple means may be obtained for controlling and improving its effect on the damping, one embodiment of such a device now being described by way example only with reference to the accompanying drawings, in which:

FIG. 1 is a horizontal section through the screw shafts in the bow of a ship fitted with bow-screws,

FIGS. 2, 3 and 4 are sectional side elevations of the damper taken on the centre-line of the ship.

FIG. 5 is a horizontal section through the propeller shafts of a ship fitted with two propellers at the stern and two propellers at the bow, showing the anti-pitch stabilizer at the bow and the balanced rudder, denoted 11. The partly dotted contour is a horizontal section of the ship at the level of the bow anchors, showing the bow anchors, denoted 12. The axis of rotation of the rudder is denoted 13, 14 and the fore propellers 15, the bosses supporting the propeller shaft for the fore propellers 15 are indicated at 17 in FIGS. 1 and 5.

FIGS. 6-11 are schematic diagrams to illustrate the proper action of the pitch damping device of the invention, giving due regard to the problem of cavitation, assuming the ship to be in the midst of the upward swing of the bow. The space enclosed by the arc-like part of the guard, denoted 1, and the hull of the ship, see FIGS. 1 and 5, is eminently suitable for fitting an anti-pitch device, the so-called damper. The damper, taken as a whole is made up of a pair of portions one situated at each side of the hull, leaving the spaces 2 between them and the forward part of the guard 1. Each of these portions is fixed to a common transverse shaft 3 and each portion is made up of parts 9 and 10. The parts of both portions are equal as are the parts 10. The transverse shaft 3 divides the damper in two nearly balanced areas of which the foremost parts 9 have a slightly higher moment on the shaft 3 than that of the afterparts 10, when hit by any flow of water. The shaft has four bearing centres, viz., two centers 4 in the guard, and two centers 5 in the hull of the ship. The shaft 3 is provided with a lever 6, and it is evident, because of the nearly balanced fore-and-after-parts of the damper, that only slight forces have to be used by the lever 6 to control the position of the damper, even at high speeds and heavy pitching. For the purpose of automatic control, the lever is fitted with two identical springs 7, fixed to the ship, see FIGS. 2, 3 and 4. When no force is exerted on the damper, the springs 7 will keep the lever 6 and the damper in their neutral position as shown in FIG. 2. In the diagrammatic showing in FIGS. 7 and 10 the portions of the line representative of parts 9 and 10 are designated respectively 9' and 10'.

Instead of springs, other kinds of resilient devices may be used.

FIGS. 2, 3 and 4 show the position of the shaft 3, the lever 6, and a vertical section of the damper projected on the centre-line plane of the ship. In FIG. 2 the ship is assumed to be running in a smooth sea and the damper, the lever and the springs maintain their neutral position. The direction of the water flow along the damper is indicated by the arrow *a*, representing the fair weather speed. In the FIGS. 3 and 4, on the other hand, the springs are alternately under different conditions of tension and compression, depending upon the position of the lever and the damper.

Any flow of water of which the direction is oblique relative to the damper, will force the damper out of its neutral position. Because of the greater moment of the flow on the foremost parts of the damper, these parts are decisive as regards the position of the damper relative to the direction of the flow. The angle of impact is controlled by the springs and may be regulated in such a way as is most desirable for damping the pitching motion.

FIG. 3 shows the position of the damper in the midst of the upward swing, which is typical for this part of the pitching motion. The midship part of the hull is in the trough, the bow in the wave crest, and the ship on an even keel. The acceleration of the upward motion at the bow has attained its highest value. The direction of the water flow at the bow, relative to the damper, is indi-

cated by the arrow *c*. The components of this force are: (1) the force *b*, representing the speed of the ship plus the orbital velocity of the water particles at the wave crest, and (2) the force *d*, representing the acceleration of the upward motion of the ship at the bow. The resultant force *c*, will force the damper in a downward position, thus enlarging the angle of impact and increasing the damping-effect. Because of the high value of the acceleration, conditions are very favourable for damping the pitching motion.

FIG. 4 shows the position of the damper in the midst of the downward swing, which is typical for this part of the pitching motion. The midship part of the hull is in the wave crest, the bow in the trough and the ship on an even keel. The acceleration of the downward motion at the bow has attained its highest value and conditions are favourable for damping. The direction of the water flow, relative to the damper, is indicated by the arrow *g*. The components of this force are: (1) the speed of the ship minus the orbital velocity of the water particles in the trough *e*, and (2) the acceleration of the downward motion of the ship at the bow *f*. The resulting force *g*, will force the damper in an upward position, thus enlarging the angle of impact and increasing the damping-effect.

In any phase of the pitching motion the effect of the damper will be more efficient than that of a device fixed to the hull. Moreover, the springs attached to the lever present a means to control the angle of impact by increasing or lessening their initial tension or compression. This makes it possible to regulate purposely the damping-effect according to the state of the sea. In a smooth sea the damper can be put out of action, if so desired.

Abutments 8, limit the stroke of the damper to prevent cavitation in the region of maximum accelerations when the ship is on an even keel and an irregularity in the seaway, otherwise, would cause cavitation.

During the pitching motion, the apparent flow at the bow is changing its direction continually over large angles of amplitude and any device for damping pitch will encounter this new and serious problem, as compared with roll damping, in connection with cavitation.

The direction of the flow depends on the speed of the ship and on the accelerations during the upward and downward swing of the bow. The accelerations at the bow are most severe when the ship is on an even keel in the midst of a swing and in this position of the ship, the angle of the flow will attain its maximum amplitude and the quenching force should attain its highest value. However, damping pitch will also change the direction of the flow and since a cavitation-free position of damping device is decisive for its proper action, it is obvious that this complicated problem will benefit from an automatic device.

In the FIGS. 6-8, a heavy sea is assumed and in the FIGS. 9-11 a moderate sea. The speed and the direction of motion of the ship is indicated by *h*.

In FIG. 6, during undamped pitch, the maximum excited accelerations *m*, and the speed of the ship *h*, yield the direction of the flow *i*, and the angle of attack *q*, with the horizontal.

In FIG. 7, after damping part of the pitching motion, the residual accelerations *p*, and the speed of the ship *h*, yield the direction of the flow *k*, and the angle of attack with the horizontal *r*, which will be called the residual angle of attack. The residual angle of attack *r*, defines the change in direction of the flow caused by the quenching force. The neutral position of the damper 10/9 is parallel to the axis of the ship and thus in the midst of a swing horizontal. The deviation of the damper out of its neutral position in FIG. 7, denoted *u*, will be called the excited angle of attack. The residual angle of attack *r*, plus the excited angle of attack *u*, yield the resultant angle of attack of the flow *k*, on the damper.

The deviation of the unbalanced damper out of its

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neutral position depends on the accelerations, which govern the direction of the flow and thus the force exerted on the unbalanced part of the damper, which defines the deviation of the damper. However, any deviation of the damper will build up the resilience of the springs to counterbalance this force.

To prevent cavitation of the damper, the stroke of the damper has to be limited, depending on the speed of the ship. This adjustment of the springs to counterbalance this extreme force on the unbalanced part of the damper has to be done in the phase of maximum excited accelerations when the ship is on an even keel in the midst of the upward and downward swing of the bow. Any discrepancy between the swings may be solved by a compromise.

In FIG. 7, the area of the damper and the resiliency of the springs is adjusted in such a way that the required part of the pitching motion is eliminated, keeping the damper just cavitation-free. This position of the damper and the springs is shown in FIG. 8, where the lever 6 is assumed to be parallel with the damper, so that the angle of the lever with the horizontal is equal to the excited angle of attack u , in FIG. 7.

In FIG. 8, the location of the abutments 8 restricts the motion of the lever, allowing between the lever and the abutments a slight margin of a few degrees, see also FIGS. 3 and 4. Any irregularity in the seaway which, otherwise, might cause serious cavitation, will keep the damper cavitation-free because the abutments will limit the stroke of the damper accordingly. However, during the normal operation of the damper, the lever 6 will not be hampered by the abutments 8 because the resiliency of the springs defines the deviation of the damper for a cavitation-free position.

FIGS. 9-11, indicate the difference in position of the damper, the lever, the abutments, etc. when damping pitch in a moderate sea, assuming the maximum excited accelerations in undamped pitch n , in FIG. 9, to be $\frac{1}{3}$ less than in a heavy sea, see m , in FIG. 6.

In FIG. 9, during undamped pitch, the maximum excited accelerations n , and the speed of the ship h , yield the direction of the flow j , and the angle of attack v , with the horizontal.

In FIG. 10 the damper will eliminate a far greater part of the pitching motion than is the case in FIG. 7. The residual accelerations o , left after damping, and the speed of the ship h , yield the direction of the flow l , and the residual angle of attack s . The damper, assumed to occupy a cavitation-free position, has a far greater deviation from its neutral position, yielding the excited angle of attack t . The residual angle of attack s , plus the excited angle of attack t , yield the resultant angle of attack of the flow l , on the damper 10/9, which is equal to that in FIG. 7, yielding the same quenching force.

However, the same resilience of the springs has to be attained with a far greater deviation of the lever 6, which is shown by FIG. 11.

In FIG. 11 this problem has been solved by using different kinds of springs 16 which allows a far greater deviation of the lever but building up the same resilience as is the case in FIG. 8, with the springs 7. It is obvious that the abutments 8, are to be located according to the adjustment of the device to this new condition of the sea, allowing a small margin of a few degrees, between the lever 6 and the abutments 8, as is the case in FIG. 8. A comparison of the FIGS. 8 and 11, will clarify this statement and prove the basic difference in purpose between the abutments and the fixed stops as used in one of the known constructions for damping pitch.

As speed increases the tuning factor will shift the critical phase relationship between wave crest and bow, as regards the seaworthiness of the ship, towards the downward swing. This so-called phase lag, caused by the speed of the ship and the wave form velocity, will not

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affect the damping-efficiency of the stabilizer in keeping the accelerations to a reasonable minimum.

Though the damper has some similarity to a balanced rudder, the differences are obvious and may be summarized as follows:

(1) In the design of the balanced rudder the axis of rotation is situated in front of the axis of balance. When released, the balanced rudder chooses its position parallel to the streamlines of a water current. For a proper action of the damper, however, the axis of rotation has to be situated behind the axis of balance. This fundamental difference is essential to give the water current a grip on the damper to make an attempt for altering this relative position between said axes, which attempt will be checked by the springs. Since it is known that the center of balance on inclined planes, caused by a flow with a small angle of attack, is located at about one-fourth of the width of the plane from the leading edge, the damper in the figures is strongly over balanced. However, the axis 3 of rotation of the damper has been located slightly more than half the width from the leading edge, to indicate that the pressure of the flow on the foremost part is greater than that on the rear part, to prevent visual confusion. For the same reason the axis of rotation of the rudder 13 has been located slightly less than half the width from the leading edge.

(2) The damper has four bearing points.

(3) The lever is situated between the bearing points.

(4) The main difference, however, between the balanced rudder and the damper is presented by the action of the springs on the lever. The springs not only have for their purpose to bring the damper to its neutral position when no force acts on its surface, but their principal purpose is to enlarge, not only automatically but even controllably, the angle of impact towards an encountering water current. This is the real deviation from the principle of the balanced rudder, where a mechanical force is needed to alter its position relative to the direction of motion of a water current. The ingenious combination of said differences makes no force necessary, besides that of the springs, to manipulate the damper for its proper action.

The operation of the damper is quite simple. In the midst of a swing, the excited accelerations, the angle of attack of the flow on the damper, the resilience of the springs, the deviation of the damper and thus the quenching force, will attain their maximum value. In this position of the ship, the resilience of the springs counterbalance the extreme force of the flow on the unbalanced part of the cavitation-free damper. After this phase, the accelerations steadily decrease to zero, when the ship is in the phase of transition from the upward to the downward swing of the bow. As a result, the angles of attack and thus the force of the flow on the unbalanced part of the damper decreases gradually and the springs will gradually force the damper back to its neutral position.

Starting the downward swing of the bow, the damper will change its position toward the horizontal, following the change in direction of the flow and during the downward swing will yield vertical lift forces. The accelerations are steadily increasing in value, changing the direction of the flow and thus increasing the force on the unbalanced part of the damper, the deviation of the damper will steadily increase and thus the quenching force. However, the resilience of the springs is building up and will limit the stroke of the damper to its adjusted ultimate cavitation-free position, when the ship is once more on an even keel but in the midst of the downward swing of the bow.

The invention as a whole is of surprising efficiency, eliminating any lapse of time between a required change in deviation of the damper and the realization of the

fin lift, which is a serious disadvantage of devices driven by motive power.

Because of the formidable quenching forces involved in damping pitch, any sudden change in these forces has to be avoided, either by cavitation or by changing the load on the damper, hence the importance of the abutments and the superiority of an automatic device.

Reducing the pitching motion means reducing the tendency of slamming and of racing of the propellers and will eliminate the harmful effects, if any, of synchronism between the natural pitching period of the ship and the period of encounter with the waves.

I claim:

1. In apparatus for stabilizing the motion of ships equipped with bow propellers, an anti-pitch stabilizer device formed as a streamlined body of a shape generally comparable to that of a balanced rudder, means for operatively positioning said stabilizer device at the bow of the ship, with portions of said device on either side of the hull of the ship, said positioning means including a common transverse axis member, said axis member being mounted for rotation with respect to said hull, said portions being mounted on said axis and said axis dividing said portions into forward and aft substantially balanced parts, said forward of said parts exerting a slightly greater turning moment on said axis when engaged by a water current than the moment exerted by said aft part, bow propellers carried by said hull and positioned aft of, but closely adjacent to, said portions, shafts carrying said propellers and shaft bosses supporting said shafts, said shaft bosses being secured to said hull and extending forwardly with respect to the same, a guard frame for protecting said portions and said bow propellers, said guard frame extending outwardly from said hull across the front of said portions down past the sides of said portions and having terminating ends supported by said

shaft bosses, the forward part of said guardframe being secured to said hull and said guardframe at positions alongside said portions being formed with bearing means in alignment with said axis member, said axis member being engaged with said bearing means for rotation therein, a control lever operatively connected to said stabilizer device and resilient devices engaged by said lever for controlling the motion thereof, said resilient devices being formed to maintain said lever and thus said stabilizing device in a neutral position when at rest for limiting the movement of said stabilizing device for a cavitation-free action thereof, said resilient means providing resilient resistance to the movement of said device in response to different sea conditions, and abutments carried by said hull and limiting the stroke of said lever to a small movement beyond said normal cavitation-free action thereof.

2. Apparatus as in claim 1 and including, said axis member being a shaft extending from said bearing means at one side of said hull, through said hull and to said bearing means at the other side of said hull, said control lever being secured to and extending radially with respect to said shaft, said control lever being positioned within said hull intermediate ends of said shaft.

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