Nov. 22, 1960 J. H. CHADWICK, JR., ET AL 2,960,959

ROLL STABILIZATION SYSTEM FOR MARINE VESSELS

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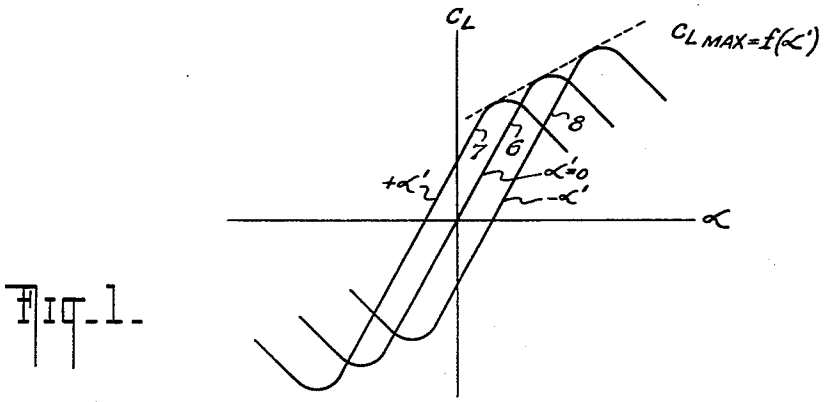


FIG. 1.

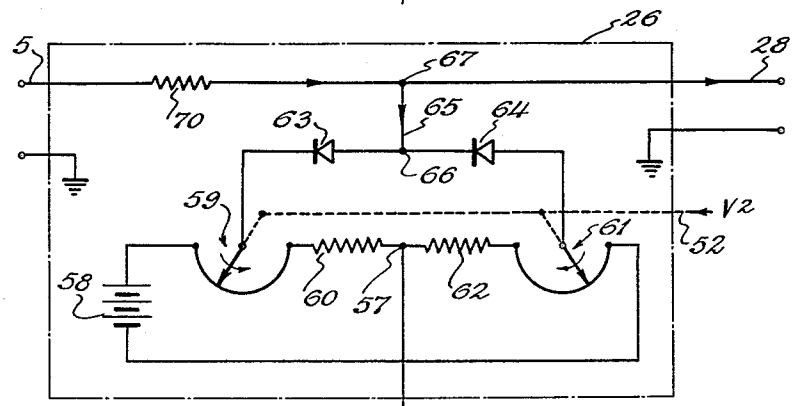
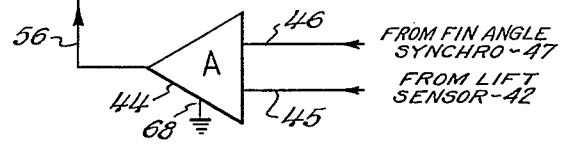


FIG. 3.



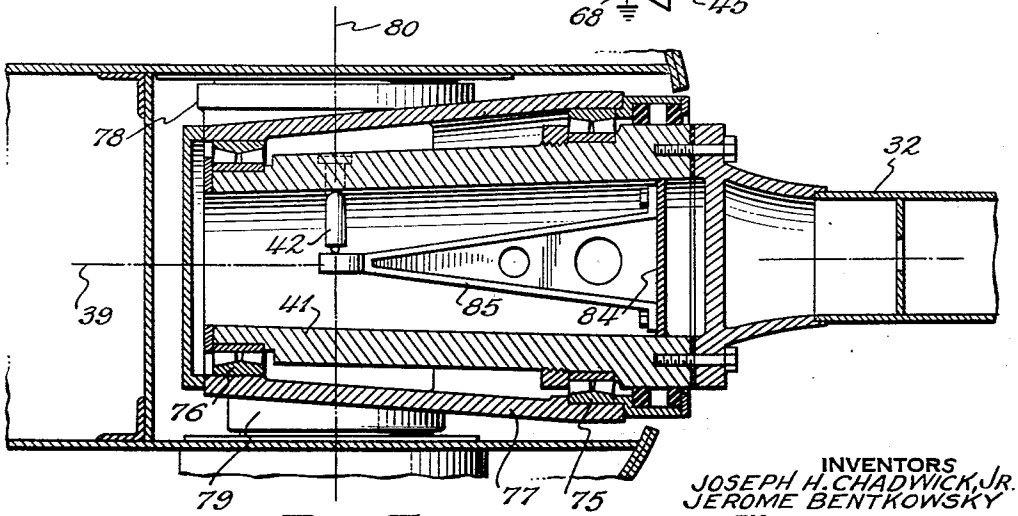


FIG. 4.

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ROLL STABILIZATION SYSTEM FOR MARINE VESSELS

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FIG. 2.

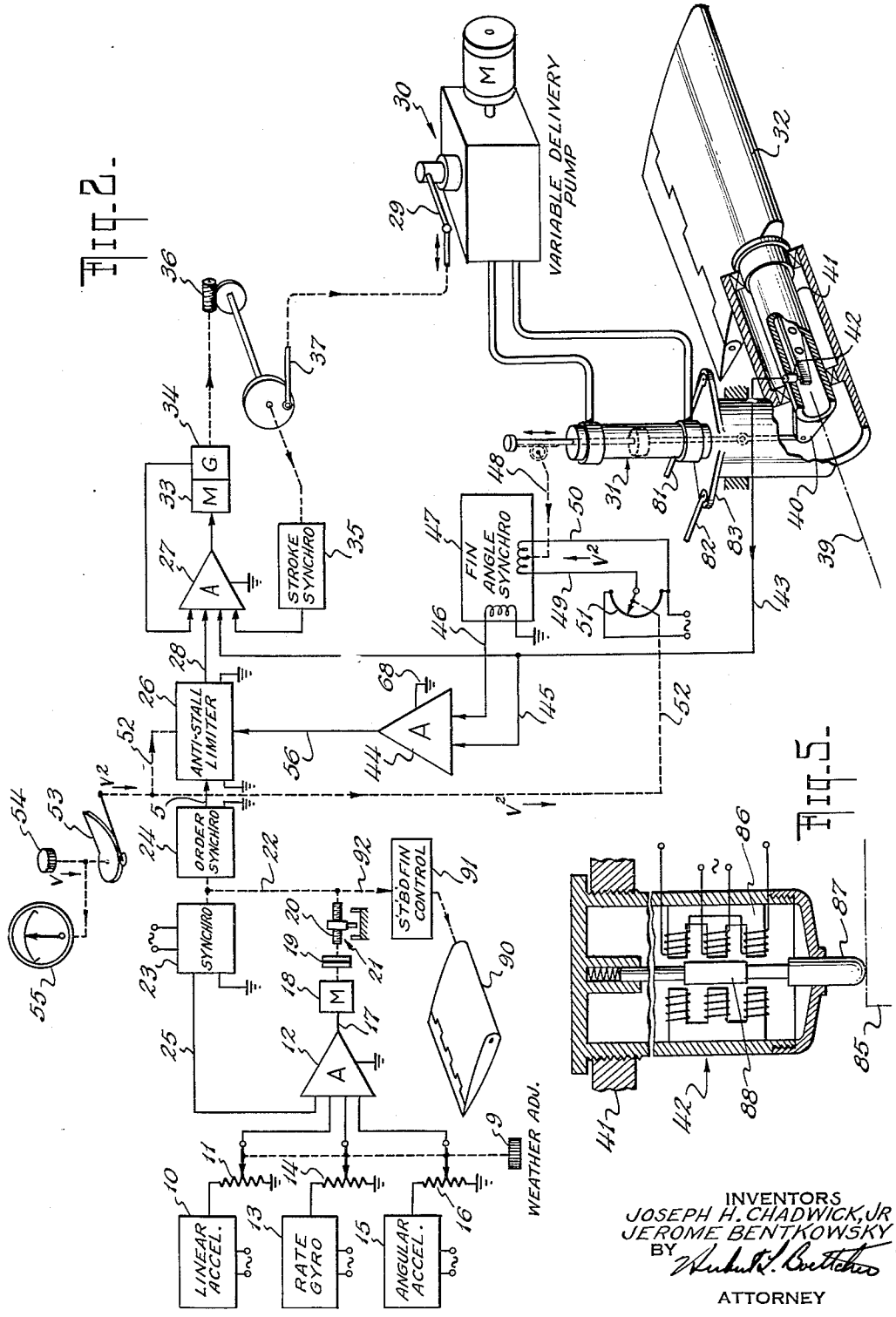


FIG. 5.

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ROLL STABILIZATION SYSTEM FOR MARINE VESSELS

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14 Claims. (Cl. 114—126)

This invention relates to activated fin control systems for the roll stabilization of marine vessels. More particularly, it concerns an improved system of this nature wherein computed lift orders for flap fins are given variable magnitude limits which follow the variations that occur in the maximum lift coefficients of the flap fins due to disturbances of the stream line at such fins and due to changes in vessel speed.

The evolution of stabilizing fins has shown a tendency towards higher and higher maximum lift coefficients, high lift being very desirable for most efficient operation. This trend has reached a plateau in the so-called flap fin, which uses a plain trailing-edge flap tiltably driven in the direction of tilt of the main fin more than one times the amount of main fin tilt to augment the maximum lift coefficient of the main fin.

However, the magnitude of a flap fin's maximum lift coefficient is affected when the flap fin is subjected to angle of attack disturbances, while the maximum lift coefficient of a conventional simple fin remains constant. The angle of attack disturbance or stream line disturbance referred to will hereinafter be termed the "false angle of attack" and is the true angle of attack of the flap fin minus its hull-referenced angle of tilt. A false angle of attack is said to be in the loading sense when it is such as to produce a greater lift than would be produced in its absence, and in the unloading sense when it is such as to produce a lesser lift than would be produced in its absence. False angles in the loading sense reduce the maximum obtainable positive lift of a flap fin and increase the maximum obtainable negative lift. Conversely, false angles in the unloading sense increase the maximum obtainable positive lift of a flap fin and decrease the maximum obtainable negative lift. Therefore, if a lift order for a flap fin is to be limited specifically to prevent the flap fin from entering into a hydrodynamic condition of stall or a state of cavitation, it is desirable that the limit imposed on the lift order be made to follow the false angle induced variation in obtainable maximum lift, at least as long as the lift order is not such as to call for a lift that would mechanically overload the flap fin and its actuating mechanism. When varied in this manner, there is no appreciable sacrifice in the system's stabilizing capacity as compared to the considerable sacrifice that would result if the lift limit were fixed near the lowest expected value of maximum lift.

Besides being affected by changes in the false angle of attack, the obtainable maximum lift for a flap fin is affected by changes in the speed of the vessel. That is to say, both the maximum positive lift and the maximum negative lift increase as the square of the speed increases.

Accordingly, by the present invention, the positive and negative limits imposed upon the lift order for each flap fin, specifically to prevent stall or cavitation, are both increased with increasing speed. And at the same time, as changes of false angle of attack occur to increase the loading on the flap fin, a decreasing limit is imposed on

computed positive lift orders, and an increasing limit is imposed on computed negative lift orders. And conversely, as changes of false angle of attack occur to decrease the loading on the fin, an increasing limit is imposed on computed positive lift orders and a decreasing limit is imposed on computed negative lift orders. Thus, insofar as speed is concerned, the positive and negative lift order limits are symmetrically controlled; while insofar as false angle of attack is concerned, the limits are anti-symmetrically controlled.

The lift order limit controlled by speed and false angle of attack is specifically to prevent stall or cavitation, and in this respect permits the computed lift orders to call for fin lifts or righting moments up to a given proportion of the maximum obtainable lift at any instant, preferably up to about 90% of this maximum.

However, there may be times when the fin lifts permitted by the anti-stall limiter would overload the flap fins and their respective actuating mechanisms. Hence, the present system is preferably also provided with an overload limiter interposed between the lift order computer and the anti-stall limiter for imposing a fixed limit on the lift order which cooperates with the variable or controlled limit, whereby both overload and stall are prevented.

The principal object of the present invention is to provide an improved activated fin control system for the roll stabilization of marine vessels.

Another object is the provision of a roll-stabilizing activated fin control system for marine vessels wherein computed lift orders for activated flap fins are given variable magnitude limits for optimum utilization of the stabilization capacity of the system.

Another object is to provide a system according to the foregoing objects wherein the variable magnitude limits follow the variations that occur in the maximum lift coefficients of the flap fins due to changes in the false angle of attack of each fin and changes in vessel speed.

Another object is the provision of a novel arrangement for symmetrically controlling the anti-stall limits of positive and negative lifts called for by an activated flap fin control system insofar as vessel speed is concerned, and for anti-symmetrically controlling such limits insofar as the false angles of attack at the fins are concerned.

With the foregoing and other objects in view, the present invention includes the novel combinations and elements described below and illustrated in the accompanying figures, wherein

Fig. 1 is a graph having lift coefficient versus angle of tilt curves for a flap fin for different false angles of attack at a given vessel speed;

Fig. 2 is a schematic diagram of a preferred embodiment of the present invention;

Fig. 3 is a wiring diagram of a suitable form of the anti-stall limiter included in Fig. 2;

Fig. 4 is a sectional view showing mounting details of a lift sensor within the drive shaft of one of the flap fins of the present system; and,

Fig. 5 is a sectional view of a suitable form of the lift sensor depicted in Fig. 4.

In Fig. 1, curve 6 shows the variation that the lift coefficient C_L of a flap fin undergoes for a given vessel speed when the angle of tilt α of the flap fin changes and when there is no false angle of attack α'. This would be the characteristic obtained in a calm sea where there is no appreciable vertical movement of the water nor of the flap-fin equipped vessel. When conditions change to produce a relative vertical movement between the sea and the vessel resulting in a false angle of attack in the loading sense, $+\alpha'$, a lift coefficient curve 7 results. Comparing

curve 7 with curve 6, it is seen that false angles of attack that increase the loading on a flap fin reduce the maximum positive lift coefficient of the fin and increase the maximum negative lift coefficient thereof. When conditions change to produce a relative vertical movement between the sea and the vessel resulting in a false angle of attack in the unloading sense, $-\alpha'$, a lift coefficient curve 8 results. Comparing curve 8 with curve 6, it is seen that false angles of attack that decrease the loading on a flap fin increase the maximum positive lift coefficient of the fin and decrease the maximum negative lift coefficient thereof.

Referring now to the schematic diagram of Fig. 2, a signal generating linear accelerometer or roll pendulum 10 is mounted with its sensitive axis disposed athwartship, and provides a reversible phase alternating current signal whose magnitude is proportional to the roll angle of the vessel and whose phase depends on the sense of the roll angle with respect to the apparent vertical. The roll angle signal is impressed across the winding of a potentiometer 11, the adjustable wiper of which is connected to the input of a summing amplifier 12.

A signal generating rate gyro 13 is mounted on the vessel so as to be sensitive to the roll rate of the vessel. The rate gyro provides a reversible phase alternating current signal whose magnitude is proportional to the roll rate of the vessel and whose phase depends on the sense of the rate. The roll rate signal is impressed across the winding of a potentiometer 14, the adjustable wiper of which is connected to the input of summing amplifier 12. This roll rate signal is the primary control signal for the system, the signal provided by the linear accelerometer 10 having to do with long term roll displacements (stabilization to the apparent vertical rather than the true vertical) and the roll acceleration signal having to do with very short term roll movements of the vessel. Thus, it is primarily the roll rate signal which commands the righting moment to be produced by the flap fin to counteract the sensed roll rate, a predetermined relation existing between the direction of the sensed roll rate and the direction of the required righting moment, e.g., the roll rate of one sense demands a righting moment of the opposite sense.

A signal generating angular accelerometer 15 is mounted on the vessel so as to be sensitive to the roll acceleration of vessel. The angular accelerometer provides a reversible phase alternating current signal whose magnitude is proportional to the roll acceleration of the vessel and whose phase depends on the sense of the acceleration. The roll acceleration signal is impressed across the winding of a potentiometer 16, the adjustable wiper of which is connected to the input of summing amplifier 12.

The three signals separately generated through the effects of vessel motion on the inertia-responsive signal generating devices 10, 13, 15 are summed in amplifier 12 to provide an amplified output representing the computed lift order which is to be limited according to the present invention. And in order that the control sensitivity of the system may be adjusted to conform with the requirements of various sea conditions that are encountered, a sea state selector or weather adjustment is provided. In the present embodiment, a knob 9 adjusts the magnitude of the sensor signals to the input of amplifier 12 by adjusting the wipers of potentiometers 11, 14, 16 simultaneously.

The lift order signal provided in the output of amplifier 12 is fed via a lead 17 to a motor 18 whose output shaft is coupled through a slip clutch 19 to a lead screw 20 forming part of a mechanical limit stop 21. From lead screw 20, a mechanical connection 22 runs to the respective rotor shafts of two variable transformer devices or synchro generators 23, 24. Synchro 23 provides, on an output lead 25 thereof, a degenerative feedback signal to amplifier 12 which controls motor 18 to drive connection 22 through a distance proportional to the lift order output signal of amplifier 12, so long as the lift called for does not exceed a limit fixed by limit stop 21. This limit is to prevent overloading the stabilizing fins, and in this regard is fixed according to the maximum load desired upon the fins. It is determined by the spacing between a pair of rigid arms arranged to cooperate with a traveling nut on lead screw 20.

When the lift called for by the output of amplifier 12 exceeds the limit fixed by limit stop 21, connection 22 is halted from being driven further upon reaching a drive distance proportional to the limit. Slip clutch 19 prevents motor 18 from being overloaded in this event.

Since the rotor shaft of synchro generator 24 is driven by connection 22, the output of synchro 24 is proportional to the computed lift order up to the overload limit imposed on the order by limit stop 21. This output is fed via a lead 5 to an anti-stall limiter 26 which is provided specifically to prevent the lift order from calling for a lift that would result in hydrodynamic stall or cavitation at the flap-fin. The limit imposed on the lift order signal by limiter 26 is variably controlled in dependence upon an electrical input proportional to the false angle of attack at one of the fins and in dependence upon a mechanical input proportional to the square of the vessel's speed.

Before proceeding with a detailed discussion of limiter 26, it is deemed advisable to enter upon a description of the elements arranged on the output side of limiter 26. Accordingly, the first of these elements is an amplifier 27 whose input receives the lift order output of limiter 26 via a lead 28. Amplifier 27 forms part of a servo loop for positioning the stroke control lever 29 of a motor-driven variable delivery pump 30 which actuates a hydraulic ram 31 to tilt one of the stabilizing fins—specifically, a flap fin 32 rigged out substantially horizontally near the turn of the bilge on the port side of the vessel.

The servo loop that includes amplifier 27 further includes a motor 33 connected to the output of amplifier 27, and a pair of signal generators 34, 35 mechanically coupled to the drive shaft of motor 33. Signal generator 34 is of the tachometer type and provides a damping or speed feedback signal to amplifier 27. Signal generator 35 is of the variable transformer or synchro generator type and provides a stroke position feedback signal to amplifier 27. The coupling between the drive shaft of motor 33 and stroke synchro 35 includes irreversible gearing 36 and a lever 37. Lever 37 operates the stroke control lever 29 of variable delivery pump 30. The output of the pump is applied to fin tilting ram 31, which ram rotates fin 32 about its tilt axis 39 through a crank 40 on a rotatable stub shaft 41 to which the fin is bolted. For every degree of rotation of fin 32, its flap is rotated through simple linkage means (not shown) somewhat further in the same direction, preferably one and a half degrees.

It is desired to have ram 31 rotate fin 32 until water pressure on the fin produces an actual lift which is equal and opposite to that called for by the lift order signal on lead 28 to amplifier 27. To accomplish this, a signal proportional to actual lift is generated by a lift transducer or sensor 42 arranged within stub shaft 41 to sense the exceedingly slight but nevertheless measurable bending proportional to lift that occurs in the fin's stub shaft. Figs. 4 and 5 respectively show how the sensor may be mounted and a suitable form of the sensor. These details will be taken up hereinafter in the specification.

The signal proportional to actual lift obtained from sensor 42 is fed to the input of amplifier 27 via a lead 43. In amplifier 27, the actual lift signal is compared to the ordered lift signal received on lead 28. The result of this comparison is an output signal or error signal from amplifier 27 proportional to the difference between the ordered lift and the actual lift, respectively represented by the signals on input leads 28, 43. Thus, the stroke control lever 29 of pump 30 and the ram 31 are actuated

according to this error signal, whereby the tilt of flap fin 32 is adjusted to obtain a lift at the fin that reduces the error signal to zero.

Besides being fed to amplifier 27 of the stroke servo, the actual lift signal is fed to the input of an amplifier 44 via a lead 45 tapped on to lead 43. Amplifier 44 receives another signal in its input via a lead 46 from one of the stator winding elements of a variable transformer device or synchro generator 47 whose rotor winding is angularly positioned according to the tilt of flap fin 32 by a mechanical connection 48 to ram 31 and energized according to the square of the vessel's speed V by a pair of electrical connections 49, 50 across the wiper arm and one side of a potentiometer 51. The potentiometer itself is energized from a source of fixed A.C. potential, and its output is caused to vary according to the square of the speed, V^2, by reason of its wiper being driven through a linkage 52 which is rotatably adjusted according to the square of the speed by the follower lever of a squaring cam 53 actuated by a speed adjustment knob 54. An indicator 55 coupled to knob 54 on the knob side of cam 53 is calibrated to show the speed for which linkage 52 is adjusted.

Due to the energization of its rotor winding according to the square of the vessel's speed, together with the angular displacement of its rotor winding according to fin tilt, the signal produced by synchro generator 47 on lead 46 is proportional to the product of the square of the vessel's speed and the fin's tilt angle, hence is proportional to the lift that would be obtained in the absence of a false angle of attack at the fin.

The purpose of amplifier 44 is to provide a control signal for the anti-stall limiter 26 that is proportional to the false angle of attack at flap fin 32. Accordingly, amplifier 44 compares the actual lift signal with the signal representing the lift that would be obtained with no false angle, and provides in its output a resultant signal proportional to the difference between the fin angle measure and the actual lift or angle of attack measure and hence proportional to the false lift which in turn is proportional to the false angle of attack.

The false angle of attack signal from the output of amplifier 44 is fed via a lead 56 to the anti-stall limiter 26. Referring now to the details shown in Fig. 3 of a suitable form of this limiter, it is seen that lead 56 connects to a tap 57. Moreover, one of the terminals of a source 58 of fixed D.C. potential, say the positive terminal, is connected to tap 57 through the winding of a potentiometer 59 in series with a fixed resistor 60. And the other or negative terminal of source 58 is connected to tap 57 through the winding of a like potentiometer 61 in series with a like fixed resistor 62. The wiper arms of potentiometers 59, 61 are connected to each other through a series pair of oppositely poled diodes 63, 64 and a lead 65 connects a tap 66 between the diodes to a junction terminal 67 for the limiter's order input lead 5, which lead also includes a voltage dropping resistor 70, and for the limiter's order output lead 28. The mechanical connection 52 (Fig. 2) rotates the wiper arms of potentiometers 59, 61 in opposite senses (as viewed in Fig. 3) in an amount according to the square of the vessel's speed. The frequency of the false angle signal output of amplifier 44 is the same as the frequency of the order input on lead 5, by reason of the common A.C. power supply for the synchros 23, 24, and 47 and force transducer 42, and the signals are either in phase or 180° out of phase, depending on the angular relationship between the rotors of synchros 24 and 47 and the direction of displacement of transducer armature 38 (Fig. 5) and hence, the phase is dependent upon the sense of the false angle of attack and the sense of the input lift order.

Limiter 26, as depicted in Fig. 3, operates in a full-wave manner. Limiting of positive half cycles of the order input on lead 5 occurs when the instantaneous magnitude of these positive half cycles, as they appear at the anode of diode 63, exceeds the instantaneous magnitude of the net positive potential from source 58 and amplifier 44 at the cathode of diode 63, whereby diode 63 conducts and grounds the order input by way of the ground connection 68 on amplifier 44. Limiting of negative half cycles occurs when the instantaneous magnitude thereof at the cathode of diode 64 exceeds the instantaneous magnitude of the net negative potential from source 58 and amplifier 44 at the anode of diode 64, whereby diode 64 conducts and grounds the order input by way of ground connection 68.

If positive lift order signals on lead 5 are of a reference phase and negative lift order signals are of opposite phase, then the false angle control signals on lead 56 are of the reference phase for unloading false angles and of the opposite phase for loading false angles.

Considering for ease of explanation only the positive half cycles of the lift order input signals on lead 5, the anti-symmetrical limiting of limiter 26 insofar as its false angle control is concerned will now become clear. When the lift order is positive and the false angle is unloading so that the respective signals therefor have the reference phase, the positive half cycles from amplifier 44 time coincident with the positive half cycles on lead 5 add to the positive D.C. potential picked off by the wiper of potentiometer 59 to produce a given limiting level for diode 63. Now if the lift order becomes negative while the false angle remains unloading, the negative half cycles from amplifier 44 time coincident with the positive half cycles on lead 5 add to the positive D.C. potential picked off by the wiper of potentiometer 59 to produce a limiting level for diode 63 that is less than the given limiting level. By similar analysis for loading false angles, it may be readily shown that the limiting level for diode 63 is less for positive lift orders than for negative lift orders. Thus, it is seen how the limits imposed by limiter 26 follow the false angle induced variations in the maximum obtainable positive and negative lifts depicted in Fig. 1.

The D.C. potential picked off by the wiper of potentiometer 59 is always positive but is adjusted in magnitude according to the square of the vessel's speed. As the vessel's speed increases, the wiper of potentiometer 59 is manually adjusted by knob 54 (Fig. 2) toward the positive side of D.C. source 58, thereby increasing tthe limiting level of diode 63 for both positive and negative lift orders. Similarly, the D.C. potential picked off by the wiper of potentiometer 61 is always negative but is adjusted in magnitude according to the square of the vessel's speed. As the vessel's speed increases, the wiper of potentiometer 61 is adjusted toward the negative side of D.C. source 58, thereby increasing the limiting level of diode 64 for both positive and negative lift orders. Thus, insofar as its control according to the square of the vessel's speed is concerned, limiter 26 acts in a symmetrical fashion.

Referring now to the mounting details depicted in Fig. 4 for the lift sensor 42, the flap fin 32 is bolted to the stub shaft 41 which is hollow in configuration. Shaft 41 is journaled in spaced bearings 75, 76 in a substantially cylindrical housing 77 for rotation about tilt axis 39. Housing 77 in turn is provided with upper and lower stub shafts 78, 79, respectively, for rotation about a substantially vertical axis 80 for fin stowage purposes. The driving force for this vertical axis rotation is obtained from a pair of stowing ram connecting rods 81, 82 (see Fig. 2) linked to a cross-head plate 83 fixed to upper stub shaft 78.

Since flap fin 32 is rigidly bolted to stub shaft 41, this shaft is subjected to the entire stress produced by water action on the fin. A circular plate 84 is rigidly secured around its rim, as by welding, to the inner surface of shaft 41 and is positioned as near as convenient to the outboard end thereof. Rigidly bolted to this plate is a cantilever beam 85 which extends substantially axially of shaft 41

toward the shaft's inboard end. Rigidly and preferably vertically secured to shaft **41** adjacent the free end of beam **85** and cooperable therewith is lift sensor **42** which senses the deflection of beam **85** due to the lift stress imparted to fin support shaft **41**, and provides a signal proportional to lift.

Any suitable type of lift sensor may be employed, and one form thereof is illustrated in Fig. 5. As shown, this sensor is an inductive pick-off device which comprises a threaded casing adjustably threaded in shaft **41** and which has fixed thereto a pick-off core and winding **86** of the E-transformer type. Two such cores may be provided for fail-safe purposes. A spring loaded plunger **87** having an armature **88** is operated by movement of cantilever **85**, and the displacement of the armature relative to the core generates in the output winding of the pick-off a signal proportional to the lift stress or actual lift. This signal, as described above, is compared with the ordered lift command output of anti-stall limiter **26**, and the fin tilting servo system reduces the difference therebetween to zero, thereby positioning the flap fin until the actual lift it imparts to the vessel is equal to the ordered lift as limited.

A mirror image **90** (Fig. 2) of flap fin **32** is rigged out on the starboard side of the vessel. A control arrangement **91** for starboard fin **90** receives the ordered lift output of the overload limit stop **21** via a connection **92** linked to connection **22**. Control arrangement **91** includes identical ones of all those components shown in Fig. 2 beginning with an order synchro corresponding to order synchro **24**. The signal phasing in arrangement **91**, however, is such that the arrangement calls for a positive lift whenever the port fin arrangement calls for a negative lift, and vice-versa. Hence, the port and starboard flap fins **32**, **90** are controlled by similar yet independent means responsive to a common source to assist each other in stabilizing the vessel in roll.

While the invention is described in its preferred embodiments, it is to be understood that the words used are words of description rather than of limitation, and that changes within the purview of the appended claims may be made without departing from the true scope and spirit of the invention in its broader aspects.

What is claimed is:

1. In a control system for an activated flap fin stabilizing surface on a marine vessel, the combination comprising, means responsive to the rolling motion of said vessel for providing a lift order signal proportional to the lift required of said flap fin to counteract said rolling motion, sensor means for providing a lift response signal in accordance with the actual lift produced by said flap fin, further means responsive to operation of said flap fin for producing a limit control signal dependent upon variations occurring in the maximum lift coefficient of said flap fin due to disturbances of the fin's angle of attack relative to its angle of tilt with respect to said vessel, means connected to receive said lift order signal and controlled in accordance with said limit control signal for varying the limits imposed on said lift order signal in accordance with said limit control signal, and means controlled in accordance with the respective sginal outputs of said last-mentioned means and said sensor means for adjusting said angle of tilt of said flap fin to reduce the difference between said required lift and said actual lift.

2. In a system for controlling the actuation of a flap fin stabilizing surface tiltably mounted below the water line of a marine vessel and projecting outwardly of said vessel on the beam thereof, the combination comprising, means responsive to the rolling motion of said vessel for providing a lift order signal proportional to the lift required of said flap fin to counteract said rolling motion, sensor means for providing a lift response signal proportional to the actual lift produced by said flap fin, controllable limiter means coupled to said lift order signal providing means for limiting said lift order signal, limiter control means coupled with said limiter for controlling the limiting level thereof according to the difference between the angle of tilt of said flap fin relative to the vessel's hull and the angle of attack of said flap fin, and means controlled in accordance with the respective signal outputs of said limiter means and said sensor means for adjusting said angle of tilt of said flap fin so that said flap fin produces an actual lift equal to the lift called for by the output of said limiter means.

3. In a marine vessel equipped with a tiltable flap fin stabilizing surface for imparting righting moments to said vessel about the vessel's roll axis, the combination comprising, means responsive to the rolling motion of said vessel for providing a signal according to the magnitude and sense of the righting moment required of said flap fin to counteract said rolling motion, sensor means for providing a signal according to the magnitude and sense of the righting moment actually produced by said flap fin, means connected to receive said sensor signal for providing a control signal according to the magnitude and loading sense of the false angle of attack of said flap fin, controllable limiter means coupled to said control signal providing means and said required moment signal providing means for limiting said required moment signal a lesser amount when it calls for an upward righting moment than when it calls for a downward righting moment providing that the false angle of attack is of a sense to decrease the loading of said flap fin, and means coupled to the respective outputs of said limiter means and said sensor means for adjusting the tilt of said flap fin to produce an actual righting moment equal to the righting moment called for by the signal output of said limiter means.

4. The system defined in claim 3 wherein the means for providing the false angle of attack signal includes means for generating a signal jointly proportional to the tilt of the flap fin and the square of the vessel's speed, and means for comparing the last-mentioned signal with the lift response signal provided by the sensor means.

5. In a marine vessel equipped with a tiltable flap fin stabilizing surface for imparting righting moments to said vessel about the vessel's roll axis, the combination comprising, means responsive to the rolling motion of said vessel for providing a signal according to the magnitude and sense of the righting moment required of said flap fin to counteract said rolling motion, sensor means for providing a signal according to the magnitude and sense of the righting moment actually produced by said flap fin, means connected to receive said sensor signal for providing a control signal according to the magnitude and loading sense of the false angle of attack of said flap fin, controllable limiter means coupled to said control signal providing means and said required moment signal providing means for limiting said required moment signal a greater amount when it calls for an upward righting moment than when it calls for a downward righting moment providing that the false angle of attack is of a sense to increase the loading of said flap fin, and means coupled to the respective outputs of said limiter means and said sensor means for adjusting the tilt of said flap fin to produce an actual righting moment equal to the righting moment called for by the signal output of said limiter means.

6. In a marine vessel equipped with a tiltable flap fin stabilizing surface for imparting righting moments to said vessel about the vessel's roll axis, the combination comprising, means for providing a signal according to the roll rate of said vessel, said roll rate having a predetermined relation to the righting moment required of said flap fin to counteract said roll rate, sensor means for providing a signal according to the righting moment actually produced by said flap fin, means responsive to said sensor signal for limiting said roll rate signal by a variable amount dependent upon variations occurring in the maximum lift coefficient of said flap fin due to disturbances of the flap fin's angle of attack relative to its

angle of tilt with respect to said vessel, signal comparison means responsive to the respective outputs of said sensor means and said limiting means for producing an error signal according to the difference between the righting moment actually produced by said flap fin and the required righting moment corresponding to the roll rate signal output of said limiting means, and drive means coupled to said comparison means for tilting said flap fin to reduce said error signal to zero.

7. In a marine vessel equipped with a tiltable flap fin stabilizing surface for imparting righting moments to said vessel about the vessel's roll axis, the combination comprising, means for providing a signal according to the magnitude and directional sense of the roll rate of said vessel, said roll rate having a predetermined relation to the righting moment required of said flap fin to counteract said roll rate, sensor means for providing a signal according to the righting moment actually produced by said flap fin, signal comparison means responsive to the respective outputs of said sensor means and said roll rate signal providing means for producing an error signal according to the difference between the righting moment actually produced by said flap fin and the required righting moment corresponding to said roll rate signal, controllable limiter means responsive to said roll rate signal for preventing the roll rate signal supplied to said signal comparison means from exceeding a preselected level which has the same magnitude for roll rate signals of one directional sense as for roll rate signals of the opposite directional sense, limiter controller means responsive to said sensor signal for providing a measure of false angles of attack of a given loading sense at said flap fin and for increasing said preselected limit level for roll rate signals of said one directional sense and decreasing said preselected limit level for roll rate signals of said opposite directional sense by an amount proportional to said false angles of attack, said limiter controller means being responsive to false angles of attack of a loading sense opposed to said given loading sense for decreasing said preselected limit level for roll rate signals of said one directional sense and increasing said preselected limit level for roll rate signals of said opposite directional sense by an amount proportional to said false angles of attack, whereby said limiter controller means anti-symmetrically controls the limiting level of said limiter means, and drive means coupled to said signal comparison means for tilting said flap fin in a sense to reduce said error signal to zero.

8. The combination claimed in claim 7 further including means for symmetrically controlling the limiting level of the limiter means in accordance with the square of the vessel's speed.

9. In a system for controlling the actuation of a flap fin stabilizing surface tiltably mounted below the water line of a marine vessel and projecting outwardly of said vessel on the beam thereof, the combination comprising, means responsive to the rolling motion of said vessel for providing a reversible phase lift order signal of magnitude dependent upon the amount of lift required of said flap fin to counteract said rolling motion and of a phase dependent upon the sense of said required lift, sensor means responsive to the loading of said flap fin for providing a lift response signal according to the actual lift produced by said flap fin, means for providing a further signal dependent upon fin operation, means responsive to said lift response signal and said further signal for providing a reversible phase control signal having the same frequency as said lift order signal and having a magnitude dependent upon the amount of the false angle of attack of said flap fin and a phase dependent upon the fin loading sense of said false angle of attack, controllable limiter means coupled to said control signal providing means and said lift order signal providing means for limiting said lift order signal a greater amount for one phase thereof than for the reverse phase thereof and vice-versa depending on the phase of said control signal, means coupled to the respective outputs of said limiter means and said sensor means for providing an error signal according to the difference between the ordered lift represented by the output of said limiter means and the actual lift represented by the output of said sensor means, and means responsive to said error signal for tilting said flap fin in a direction and amount to reduce said error signal to zero.

10. In a control system for an activated flap fin roll stabilizing surface on a marine vessel, the combination comprising, inertial means responsive to the rolling motion of said vessel for providing a lift order signal having a magnitude and sense according to the lift required of said flap fin to counteract said rolling motion, sensor means responsive to the hydrodynamic loading imparted to said flap fin for providing a lift response signal having a magnitude and sense according to the lift actually produced by said flap fin, limiter means coupled to said inertial means for imposing anti-symmetrically varying stall prevention limits on opposite senses of said lift order signal, limiter control means responsive to said lift signal for controlling the anti-symmetrical variation of said limits about a preselected common level thereof according to the magnitude and sense of said fin loading, signal comparison means coupled to the respective outputs of said limiter means and said sensor means for providing an error signal according to the difference between the ordered lift represented by the signal output of said limiter means and the actual lift represented by the signal output of said sensor means, and drive means coupled to the output of said comparison means for activating said flap fin to reduce said error signal to zero.

11. In a roll stabilization system for marine vessels having an activated fin for imparting righting moments to said vessel about its roll axis and servomotor means for tilting said fin with respect to said vessel, the combination comprising, means for supplying a first control signal in accordance with roll movements of said vessel, means for supplying a second control signal in accordance with the lift imparted to the vessel by said fin, means for supplying a third control signal in accordance with the angle of tilt of said fin relative to said vessel, variable limit means connected to receive said first control signal for limiting the magnitude thereof, means responsive to said second and third control signals and coupled with said limit means for varying the limits imposed on said first control signal, and means responsive to said limited first control signal and said second control signal for supplying a servomotor control signal.

12. In a roll stabilization system for marine vessels having an activated flap fin for imparting righting moments to said vessel about its roll axis and servomotor means for tilting said fin with respect to said vessel, the combination comprising, means for detecting and supplying a measure of the roll movements of the vessel, means for detecting and measuring both the angular displacement of the flap fin with respect to the vessel and the lift imparted to said vessel by said flap fin, means responsive to both said fin angle and fin lift measures for supplying a measure of the false angles of attack of said fin, means for providing a measure in accordance with the speed of the vessel, and variable limit means responsive to said false angles of attack measure, said speed measure, and said roll movement measure for limiting the magnitude of the roll movement measure within upper and lower limits in accordance with changes in the value of the false angles of attack measure and said speed measure, said variable limit means being so constructed and arranged that the upper and lower limits imposed on said roll movement measure are anti-symmetrically varied in accordance with said false angles of attack and symmetrically varied in accordance with said speed measure.

13. In a roll stabilization system for marine vessels having at least one fin extending outwardly from the hull and adapted upon tilting thereof to produce righting couples on the vessel and motive means for tilting said fin, the magnitude of the maximum lift coefficient of said fin increasing with the magnitude of the angle of attack thereof, apparatus for optimizing the lift capability of said fin under conditions of variation in the direction of the local flow streamlines at said fin, comprising means for supplying a lift command signal, means for controlling said motive means in accordance with said command signal, and means for modifying said command signal to prevent said fin from exceeding an angle of attack corresponding to said maximum lift coefficient, said modifying means including means for limiting both positive and negative excursions of said lift command signal, means for producing a signal representative of the component of velocity of said local flow streamlines mutually perpendicular to the tilt axis of said fin and the longitudinal axis of the vessel, and means responsive to said last-mentioned signal for varying antisymmetrically the positive and negative limits imposed by said limiting means upon said lift command signal.

14. In a roll stabilization system for marine vessels having at least one fin extending outwardly from the hull and adapted upon tilting thereof to produce righting couples on the vessel and motive means for tilting said fin, the magnitude of the maximum lift coefficient of said fin increasing with the magnitude of the angle of attack thereof, apparatus for optimizing the lift capability of said fin under conditions of variation in the direction of the local flow streamlines at said fin, comprising means for supplying a lift command signal, means for controlling said motive means in accordance with said command signal, means, for providing a signal representative of the component of velocity of said local flow streamlines mutually perpendicular to the tilt axis of said fin and the longitudinal axis of the vessel, and means for modifying said lift command signal in accordance with the signal of said last-mentioned means for preventing said fin from exceeding an angle of attack corresponding to said maximum lift coefficient.

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