Feb. 13, 1962 L. F. BEACH 3,020,869

ACTIVATED FIN SHIP STABILIZER

Filed Aug. 12, 1959 2 Sheets-Sheet 1

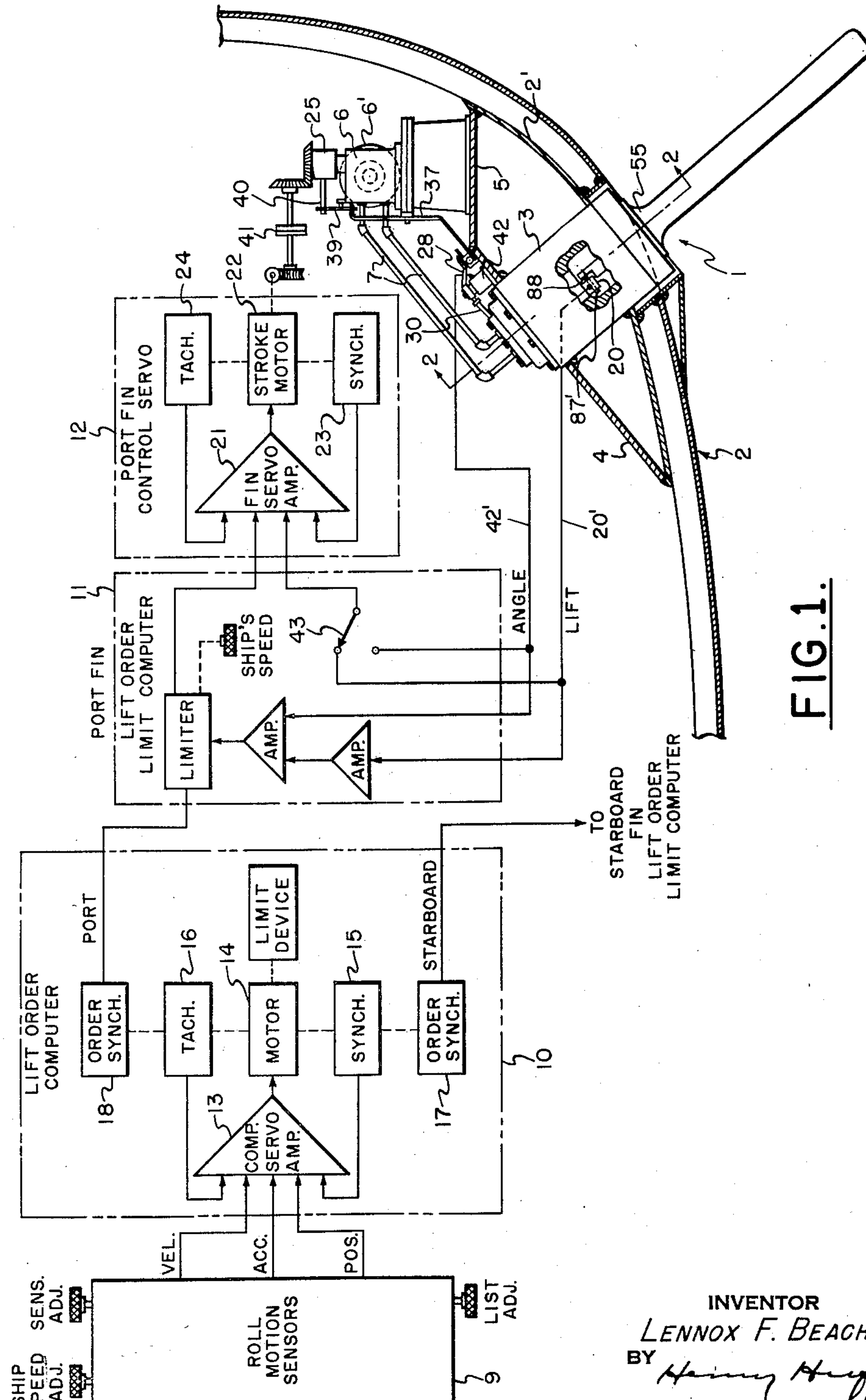

FIG. 1.

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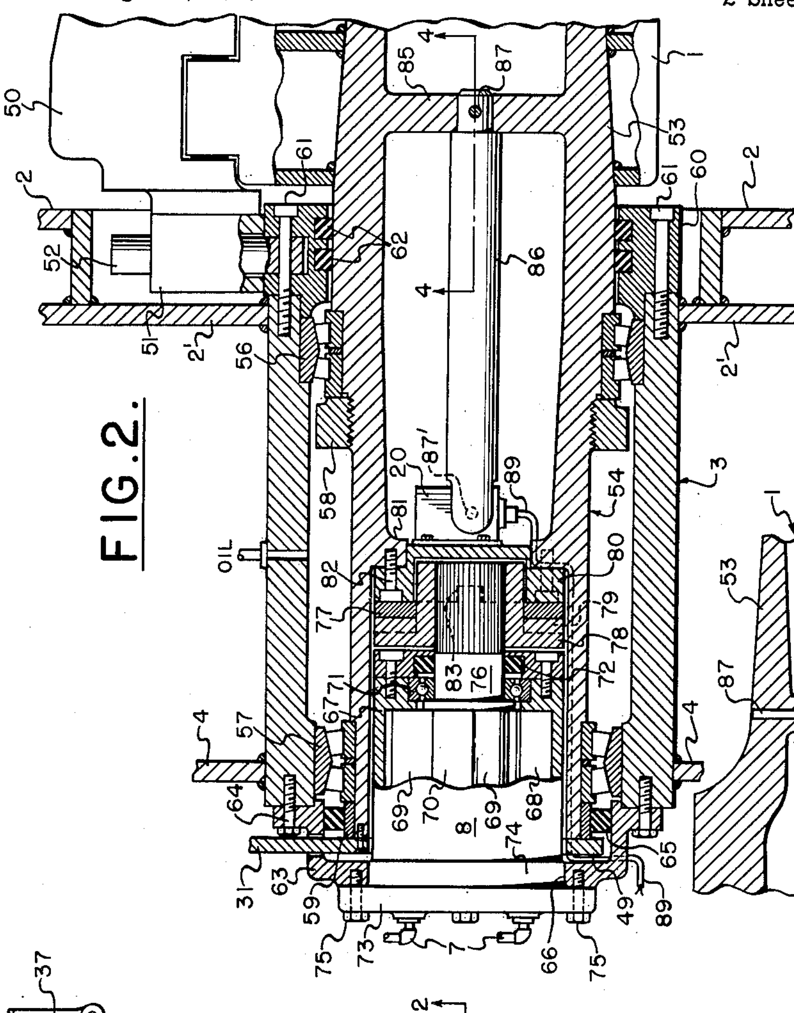

FIG. 2.

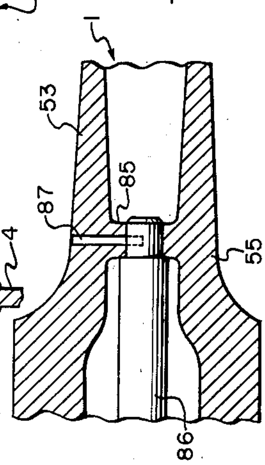

FIG. 4.

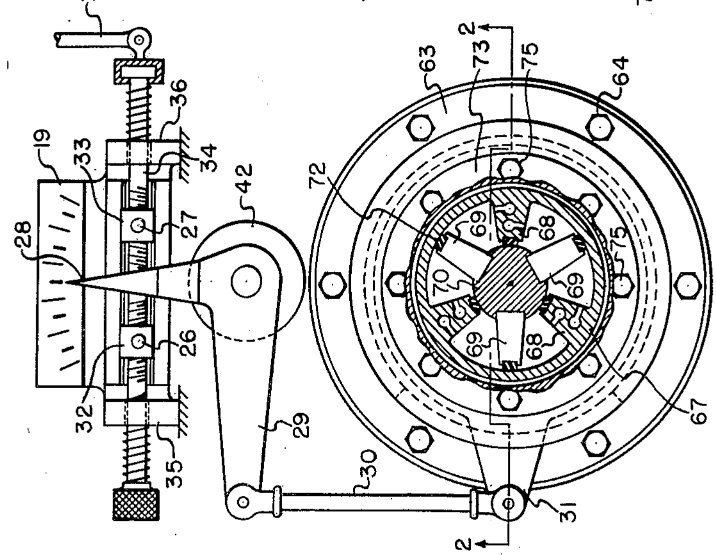

FIG. 3.

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ACTIVATED FIN SHIP STABILIZER

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8 Claims. (Cl. 114—126)

The present invention relates generally to stabilizers for marine vessels and more particularly to ship stabilizers which employ preferably pairs of underwater activated fins projecting outwardly from the ship's hull and which are controlled upon rolling of the ship to tilt in such directions and magnitudes as to produce lift forces on the ship which oppose such rolling and thereby maintain the ship substantially upright at all times.

In general, stabilizers of the above character comprises a heavy machinery portion for each fin located in the ship's hull and which includes the fin itself and its operating hydraulic gear and gear controls; and a single control system usually located on the bridge and which comprises various sensors for sensing the roll motions of the vessel together with apparatus for computing from signals proportional to the sensed roll motions the roll moment or force required to be produced by the fins to oppose such rolling, the latter computed roll moment information being in the form of an electrical command signal which is transmitted to each fin station and which controls the hydraulic gear to position each of the fins in accordance therewith.

In my copending joint application Serial No. 516,662, now United States Patent No. 2,979,010 filed June 20, 1955, for "Ship Stabilization System," I have shown and described in detail an activated fin ship stabilization system of the above character. In that application, one of the novel concepts is the use in the fin control servomotor system of a feedback signal which is proportional to the actual lift exerted on the ship by the fin rather than a feedback signal which is proportional to the angle that the fin makes with the vessel. As taught in that application, the advantage of the use of such a lift feedback signal is that the fins produce a pure couple on the ship regardless of the direction of water flow along the ship's hull. Since a common lift order signal is applied to independently operable fins located on opposite sides of the hull and since each fin produces a lift in accordance with this signal but in opposite senses, this equality of fin forces provides maximum effectiveness of the stabilizer system. This same principle is employed in the stabilization system of the present application.

In the above-mentioned copending application, the fins are stowed within the hull of the ship when not in use. While the novel features of the present invention may be readily applied to such a stowable fin system, the fins of the present invention are hereindisclosed in a system wherein the fins are non-retractable. Some classes of marine vessels, for example, narrow beam vessels such as destroyers have extremely limited hull space and in this type of vessel retractable fins may not be desirable. The fin structure disclosed herein is ideal for such non-retractable fin installations, since the hold space required for the fin support and actuating mechanism is kept to a minimum and yet, with the present novel design, the actuating mechanism is readily accessible from within the hull for overhaul and repair.

Thus, an object of my invention is to provide an improved activated fin ship stabilizer wherein the hull space required for the fin mount and its actuating machinery is minimized and readily serviceable without dry-docking.

One feature through which the above object is realized resides in the fact that the trunnion which supports the fin in the hull for tilting movement relative thereto is

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hollow and the fin drive motor is located within this hollow trunnion thereby avoiding the space which would otherwise be required for the fin drive motor. In the present apparatus, the hollow fin support trunnion is mounted for rotation in a double-ended bearing frame that is fixed at one end to the hull of the ship or vessel below its waterline. The casing and rotor of the fin drive motor are removably connected to the other end of the frame as a cantilever member that supports the rotor within the hollow trunnion. A coupling that permits removal of the motor from the open end of the trunnions connects the rotor of the motor and trunnion.

It is therefore another object of my invention to provide an improved activated fin ship stabilizer wherein the casing and rotor of fin drive motor are located within the mounting trunnion for the fin thereby minimizing the space required for the fin machinery.

Accurate and rapid positioning of the fin is essential to effective operation. Under some operating conditions, the fin may move from one extreme angular position to the other in 1½ seconds. Response of this order requires machinery free of a multiplicity of load carrying parts, and having the actuating motor coupled mechanically adjacent to the fin.

Accordingly, it is a further object of my invention to provide an improved activated fin ship stabilizer wherein the torsional forces which serve to tilt the fin are carried by members of minimum length and maximum diameter, in order to reduce torsional deflection in such members to a minimum.

As taught in the above-mentioned copending application, I have likewise herein employed a feedback signal proportional to the actual lift exerted by the fin as a result of water forces acting thereon. In the present invention, the trunnion is cylindrical and it tapers into the fin or hydrofoil portion just exteriorly of the hull line of the vessel. Therefore, at this tapered portion, the lift forces exerted by the fin are transferred to the trunnion and hence it is at this point that the greatest stress and therefore deflection on the fin and shaft structure occurs. I utilize this fact in generating the lift feedback signal. For this purpose, I securely attach one end of a rigid arm to a web portion of the fin adjacent the tapered area of the fin, the arm extending along the axis of the hollow fin trunnion. Thus, maximum deflection of the free end of the arm is available to actuate the lift signal generator or force transducer.

With my improved design, the parts of fin drive motor and one of the parts of the lift transducer may be readily removed and serviced from within the vessel's hull to thereby obviate the necessity of dry-docking the vessel for such service. For this purpose, a bearing frame or housing is welded to the ship's hull and suitable support plating also welded to the hull structure. The fin trunnion is journalled in frame or housing by spaced bearings and hydraulic seals between the frame or housing and trunnion are provided for preventing sea water from leaking along the exterior of the trunnion. The casing of the fin drive motor may include a flange that closes the inboard end of the bearing housing.

It is therefore a further object of the present invention to provide an improved activated fin ship stabilizer wherein the fin drive motor and a portion of the lift transducer may be readily removed and serviced from within the hull of the vessel.

Other objects and advantages of the present invention will become apparent as the description of a preferred embodiment thereof proceeds, reference being made to the accompanying drawings wherein:

FIG. 1 is a schematic diagram of the fin stabilizer including the control portion thereof and one of two of the identical fins and its heavy machinery portion;

FIG. 2 is a cross-sectional view of the fin trunnion and trunnion support mechanism taken along the line 2—2 of FIG. 1;

FIG. 3 is an end view, partially in section of the fin trunnion and support and showing schematically the fin drive motor; and

FIG. 4 is a partial sectional view of the tapered portion of the fin taken along line 4—4 of FIG. 2.

Referring now to FIG. 1, the activated stabilization fin is designated by a reference character **1** and is of conventional symmetrical hydrofoil configuration with a full trailing edge flap. The fin is supported in the hull of the vessel **2** by means of a bearing frame or housing **3** which is suitably welded at its outboard end in the hull plating and at its inboard end in support plating **4** and **5** welded to the ship's hull structure. Only the port fin has been illustrated in the drawings, it being understood that the starboard fin is identical. Since, in the illustrated embodiment of the present invention, the fins are non-retractable, they are mounted in the hull so as to extend outwardly from the hull at a substantial angle with respect to the waterline, i.e., at approximately 45 degrees, whereby the outer tip of the fin lies within the over-all beam of the vessel, i.e., within the deck line of the vessel. This enables the vessel to come alongside a dock or pier without danger of damage to the fin.

Mounted on horizontal mounting plate **5** is a hydraulic power unit which comprises generally a variable delivery hydraulic pump **6** driven by a heavy duty electric motor **6'**, the pump **6** supplying controlled high pressure fluid through hydraulic lines **7** to a hydromotor or hydraulic motor **8** (FIG. 2) for driving the fin **1**. The hydraulic power unit **6, 6'** may be substantially identical to that shown and described in detail in my above-mentioned copending application and a detailed discussion thereof will not be repeated herein.

The control system for the fin comprises generally roll motion sensors **9**, a lift order computer **10**, a lift order limit computer **11**, and a fin control servo system **12** which governs the delivery of the variable delivery pump **6**. The roll sensors **9** and lift order computer **10** may be housed in a suitable console located on the bridge of the vessel while the lift order limit computer **11** and fin servo system **12** may be located at the fin stations.

Basically, it is the function of the control portion of the stabilizer system to detect the roll motions of the vessel and compute therefrom the moment required to oppose such motions. Three components of ship's roll motion are detected: roll angle, roll velocity, and roll acceleration. As shown in the above-mentioned copending application, these components are detected by a linear accelerometer or inverted pendulum, a roll rate gyro, and an anular accelerometer, respectively. Roll velocity is the primary term while the roll angle, as measured by the inverted pendulum, detects transverse acceleration and stabilizes the ship to the apparent vertical rather than the true vertical. Roll acceleration is used to provide a smoother ride when roll disturbances are above the vertical frequency of the ship. These signals are supplied to a computer servo amplifier **13** where they are proportioned one to the other in desired ratios, amplified, and then supplied to a computer servomotor **14** which drives through an angle, by means of position feedback synchro **15**, proportional to the lift requred of the fin to oppose the detected rolling motion. A tachometer **16** is provided for damping the computer servo loop. A mechanical limit device, preferably adjustable in accordance with ship's speed, limits the maximum command signal that can be supplied to the fin control servos. Servomotor **14** drives a starboard order synchro **17** and a port order synchro **18** which supply the lift command signal to the port and starboard fin servo systems, the two signals being 180° out of phase to effect opposite fin movements.

As set forth in detail in my above-mentioned copending application, the computer output is a signal proportional to the proper lift required of the fins in terms of the angle of attack thereof with respect to the water. Since the lift produced on the fin by water force is substantially the same as the angle of attack of the fin with respect to the water flow, a signal proportional to the fin lift is provided and is fed back into the control system to cancel the ordered lift signal when the actual lift equals the ordered lift. This lift signal is obtained from a lift sensor or lift transducer **20** which is actuated in accordance with the stress experienced by the hydrofoil fin **1**. The lift command signal is supplied to a lift order limit computer **11** where it is limited in accordance with a function of the angle that the fin makes with respect to the hull, the lift exerted by the fin on the hull, and ship's speed. The above limitation of the lift order signal is described and claimed in copending application Ser. No. 610,210, now Patent No. 2,960,959 filed September 17, 1956, in the names of J. H. Chadwick and J. Bentkowsky for "Roll Stabilization System for Marine Vessels," assigned to the same assignee as the present invention, and its operation will not be discussed in detail in the present specification. It is sufficient to say that the lift order limit functions to keep the lift orders within the linear boundaries of the coefficient of lift characteristics of the fin for commanded angles of attack to thereby minimize fin cavitation with its attendant inefficiency or drag and objectionable rumble.

The limited lift order or lift command signal is applied to the amplifier **21** of the fin positioning servo system **12**, the output of which is connected to control the position of stroke servomotor **22** through operation of position feedback synchro **23**. As in the case of the lift order computer servo, the fin positioning servo loop is stabilized by means of a suitable rate damping voltage produced by tachometer **24**. The mechanical output of stroke servomotor **22** positions the stroke control member **25** of variable delivery pump unit **6** to thereby control the flow of hydraulic fluid to hydromotor **8** which positions the fin. As stated, the fin lift feedback signal from lift transducer **20** closes the fin positioning servo loop while the response of the ship to the deflected fin closes the over-all system loop.

In order to limit fin deflections within the mechanical capabilities of the fin and its support structure, a mechanical fin angle limiting means is provided. This mechanical limit may be essentially the same as that disclosed in my copending application and may comprise a pair of preferably adjustable limit stop pins **26** and **27** and arm **28** positioned directly in accordance with the movement of the fin with respect to the ship through linkages **29, 30** and **31**; see FIGS. 2 and 3. Limit stop pins **26** and **27** are mounted on blocks **32** and **33**, respectively and slideably mounted on mating keyways in member **19** fixed in the ship. The spacing of blocks **32** and **33** is adjustable either manually or by a suitable motor drive by means of oppositely pitched threaded shaft **34** which is both rotatably and slideably mounted in suitable bearings **35, 36** on member **19**. Suitable springs are provided for normally centering the stop pins with respect to member **19**. One end of shaft **34** is coupled with a pivoted stroke limiting arm **37** through a rotatable coupling and positions a pivoted yoke **39** (FIG. 1) the open ends of which embrace an arm **40** on stroke control **25** to thereby limit the motion of the latter. A suitable slip clutch **41** is provided for protecting stroke control motor **22**. From the foregoing described structure, it is evident that if the ordered lift command tends to produce a deflection of greater magnitude than is mechanically possible or desired, the arm **28** contacts one or the other of the projections **26, 27** and slides the shaft **34** in bearings **35, 36** which, through link **37**, moves one or the other arms of the yoke **39** into contact with arm **40** to thereby reposition the latter in a direction to stop further fluid flow to the fin positioning hydromotor **8**. The limit stop arrangement just described overpowers all other orders to pump stroke control **25** of the variable delivery pump **6**.

The signal proportional to the angle that the fin makes with respect to the ship is supplied by means of a synchro **42** connected in the fin angle linkages **29, 30** and **31** while, as stated, the signal proportional to fin lift is provided by means of transducer **20**. The angle signal and lift signal are supplied to the lift order limit computer **11** by way of respective leads **42'** and **20'** for limiting the lift order signal in a manner set forth in the above-mentioned application Ser. No. 610,210. If desired, and as disclosed in my copending application, the fin may be controlled in accordance with either fin angle or fin lift through means of selector switch **43** through which either lead **42'** or lead **20'** is connected to the fin servo amplifier **21**.

The novel features of the improved fin stabilizer of the present invention will now be described, reference being made particularly to FIGS. 2, 3 and 4 of the drawings. As hereinabove stated, these novel features reside in the particular fin mounting and drive structure, the advantage of which is to minimize the hold space required for the installation, and to provide a torsionally stiff fin tilt mechanism. The fin mounting structure comprises generally a tubular or cylindrical fin bearing frame or housing **3** rigidly welded in place in the hull plating **2'** and fin support plating **4**. The housing thus forms a rigid casing for transferring the force produced by the fin to the ship's hull structure. The fin **1** comprises a symmetrical hydrofoil of conventional spar, rib, and plating fabrication. The fin is provided with a full trailing edge flap **50** which is moved through an angle greater than but in the same sense as the main fin **1**. The latter movement is obtained by means of a slipper block **51** fixed to the flap and a link **52** pivoted on the ship on an axis displaced from and parallel to the main fin tilt axis. In the illustrated embodiment of the invention, the main fin spar is designated by reference character **53** which tapers into a cylindrical trunnion **54**, this taper being illustrated clearly at **55** in FIGS. 1 and 4. Preferably, the spar, taper and trunnion are fabricated as a single metal casting. In accordance with the teachings of the present invention, the trunnion **54** is hollow and is mounted in the frame or housing **3** by means of inboard pairs of tapered roller bearings **56** and inboard pairs of tapered roller bearings **57**. The roller bearings **56** are mounted on the trunnion and secured thereto by means of collar **58** while the roller bearings **57** are of lesser diameter than roller bearings **56** (for assembly purposes) and are likewise mounted on the trunnion and held in place by means of collar **59**. Collar **59** is fixed against axial movement by annular plate **49** secured to the end of trunnion **54**. An extension **31** of plate **49** is part of the fin position linkage system described above. The hollow trunnion and bearing assembly is fixed against axial movement in housing **3** by means of an end collar **60** which is rigidly secured to the frame **3** by means of a plurality of annularly spaced bolts **61**, one of which also serves as a pivot for the flap actuating link **52**. Sea water is prevented from leaking along the trunnion **54** and into the housing **3** by means of a pair of hydraulic seals **62** mounted in suitable annular grooves in collar **60**.

The open end of housing **3** is closed by means of an end cap **63** rigidly secured to the housing **3** by means of annularly spaced bolts **64**. A further hydraulic seal **65** between the end cap **63** and collar **59** is provided. Preferably, the space between hollow trunnion **54** and support casing **3** is filled with oil for lubricating the bearings and which may be maintained at a pressure substantially equal to the water pressure at the normal depth of the fin to further inhibit sea water leakage.

The drive means for the fin comprises a fluid operated motor **8** shown partially in section in FIGS. 2 and 3. This motor may be a conventional rotary hydraulic motor or hydromotor having a cylindrical casing **67** and internally projecting walls **68** which may contain fluid conduits for supplying fluid pressure from the motor manifolds at the inboard end of the motor to the desired interior chambers thereof. Vanes **69** are mounted on the rotor **70** and respond to differential fluid pressure across the vanes to rotate the rotor accordingly. Differential fluid pressure is supplied to drive the motor in one direction or the other through conduits **7** connected to the output of variable delivery pump **6**. The motor is provided with the usual bearings **71** and hydraulic seals **72**.

The casing **67** of the hydromotor includes a flanged end portion **73** and a boss **74**, the latter fitting within the opening **66** in the end cap **63** of the housing **3** with the flange portion **73** being detachably secured thereto by means of annularly spaced bolts **75**. Thus, the removable casing **67** and rotor **70** of the hydromotor **8** are connected to the inboard end of the frame or housing **3** as a cantilever member that supports the rotor within the hollow trunnion part of the fin spar. The hydromotor output shaft **76** is coupled with the trunnion by means of a conventional crossed ridge and slot coupling means which allows any slight lateral or angular misalignment from coaxial relation which may exist between the motor drive shaft and the trunnion axis of rotation. This coupling means which permits removal of the spar motor from the inboard open end of the trunnion is adapted to surround the drive shaft **76** and comprises a central member **77** which has a ridge on one side and slot on the other arranged at right angles to each other. A second member **78** of coupling **77** is splined to motor shaft **76** and has a corresponding ridge **79** therein mating with the slot of member **77** while a third member **80** of the coupling **77** is detachably secured to an annular inwardly projecting flange **81** in the trunnion **54** by means of annularly spaced bolts **82** and is provided with a slot **83** which mates with the corresponding ridge of member **77**. The third member **80** of coupling **77** when assembled in the trunnion forms a wall or removable plate dividing the hollow trunnion into two compartments, one containing the drive motor **8** and the other containing the lift transducer **20** as will now be described.

As stated above, the cylindrical trunnion **54**, the fin main spar **53** and a connecting tapered portion **55** are all preferably cast as one integral element. The diameter of the cylindrical trunnion **54** is larger than the thickness of hydrofoil **1** so that a fillet or taper is necessary to join the foil section smoothly to the trunnion section. Since this taper joins the trunnion to the substantially flat portion of the fin and since the flat portion of the fin produces the lift force, the flanged or tapered portion of the fin experiences the greatest stress, a stress which tends to bend the fin adjacent the tapered portion. According to a feature of the present invention, I have placed a web **85** that extends transversely of the spar axis adjacent the flange portion **55** of the fin and inserted into a hole in this web portion an arm or shaft **86** which is rigidly secured to said web and held in place by means of a pin **87**. Thus, the arm or shaft **86** which extends along the axis of the spar is connected at one end to the web **85** of the fin **1**. It should be noted that the point in the fin at which the shaft **86** is secured lies exteriorly of the hull line of the vessel and extends inwardly into the other chamber of the hollow trunnion **54** thus providing a relatively long cantilevered arm. Since the shaft **86** is relatively long and its point of attachment is adjacent the point of greatest stress experienced by the fin, the free end of shaft **86** will move in response to relatively small lift forces on the fin.

As shown in FIGS. 1 and 2, the free end of shaft **86** is coupled with the force or lift transducer **20** so that any movement or deflection at the free end of the shaft **86** is transformed into an electrical signal proportional to such deflection and hence proportional to the lift exerted by the fin. The force transducer **20** may be identical with that disclosed in my above-mentioned copending application and therefore need not be described in detail herein. It need only be stated that the transducer includes a pin **87′** which is spring-pressed onto a flattened surface **88** of the arm or shaft **86**, the pin actuating directly and forming a part of the movable part of a signal generator such as, for example, the armature of an E-type pick-off or other suitable inductive pick-off. The electrical conduit **89** of the pick-off **20** may be brought out of the trunnion by means of suitable grooves cut in the trunnion internal wall. The other part of the lift transducer or signal generating means **20** is secured in fixed relation to the removable plate **80**.

From the foregoing description, it will be readily apparent that the casing and rotor of the hydromotor **8** and a portion of the lift transducer **20** may be easily removed from the open end of the trunnion **54** for inspection, overhaul and/or repair from within the hull of the vessel thereby eliminating any necessity for costly dry-docking of the vessel for this purpose. This may be accomplished by detaching hydraulic lines **7**, removing bolts **75**, and then sliding the entire hydromotor **8** out of the hollow trunnion **54**. The coupling members **77** and **78** may then be removed thereby exposing bolts **82** which secure the wall **80** to the fin trunnion. Upon removal of these bolts, the coupling part or plate **80** together with its attached lift transducer **20** may likewise be removed as a unit from the trunnion, all of the foregoing being accomplished from within the hull of the vessel since the end cap **63**, seals **65** and **62** need not be disturbed. The structure may be reassembled in reverse order upon completion of the necessary overhaul and/or repair.

While the invention has been described in its preferred embodiment, it is to be understood that the words which have been used are words of description rather than 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 marine vessel with a non-retractable stabilizing fin movable about an axis, a double-ended inboard bearing frame providing the fin axis fixed at one end to a portion of the hull of the vessel below its waterline, a spar having a hollow inboard trunnion part open at one end journaled in the bearing frame to move about the axis and having an outboard fin part, a fin drive motor having a removable casing and rotor connected to the other end of the frame as a cantilever member supporting the rotor within the hollow trunnion part of the spar, and a coupling between the rotor and trunnion part permitting removal of the motor from the inboard open end of the spar trunnion part.

2. In a marine vessel with a non-retractable stabilizing fin movable about an axis, a double-ended, inboard, bearing frame providing the fin axis fixed at one end to a portion of the hull of the vessel below its waterline, a straight spar having a hollow inboard trunnion part open at one end journaled in the bearing frame to move about the axis and having an outboard fin part, means for moving the spar about its axis having a removable casing and rotor connected to the other end of the frame as a cantilever member supporting the rotor within the hollow trunnion part of the spar, and means for disengageably coupling the rotor and trunnion part to permit removal of the moving means from the inboard open end of the trunnion part of the spar.

3. In a marine vessel with a non-retractable stabilizing fin movable about an axis, an inboard frame having axially spaced bearings providing the fin axis fixed at one end to a portion of the hull of the vessel below its waterline, a straight spar having a hollow inboard trunnion part open at one end extending between the bearings to move about the axis and having an outboard fin part, a hydromotor having a removable casing and rotor connected to the other end of said frame as a cantilever member supporting the rotor within the hollow trunnion part of the spar in coaxial relation to the axis of the spar, and a coupling between the rotor and hollow trunnion that permits removal of the hydromotor from the inboard open end of the trunnion part of the spar.

4. In a marine vessel with a non-retractable stabilizing fin movable about an axis, an inboard housing having axially spaced bearings providing the fin axis fixed at one end to a portion of the hull of the vessel below its waterline, a straight spar having a hollow inboard trunnion part open at one end extending between the bearings to move about the axis and having an outboard fin part, a hydromotor having a removable flanged casing and rotor connected to close the other end of said housing as a cantilever member supporting the rotor within the hollow trunnion part of the spar in coaxial relation to the axis of the spar, and a coupling between the rotor and hollow trunnion that permits removal of the hydromotor from the inboard open end of the trunnion part of the spar.

5. In a marine vessel with a non-retractable stabilizing fin movable about an axis, a double-ended, inboard bearing frame providing the fin axis fixed at one end to a portion of the hull of the vessel below its waterline, a fin spar having a hollow inboard trunnion part open at one end journaled in the bearing frame to move about the axis, a fin spar drive motor having a removable casing and rotor connected to the other end of the frame as a cantilever member supporting the rotor within the hollow trunnion part of the fin spar, and a coupling between the rotor and trunnion part permitting removal of the motor from the inboard open end of the spar trunnion part.

6. The combination claimed in claim 5, in which said frame is a housing having axially spaced bearings, and the casing of the spar drive motor includes a flanged portion that closes the other inboard end of the housing.

7. In a marine vessel with a stabilizing fin movable about an axis, a double ended, inboard bearing frame providing the fin axis fixed at one end to a portion of the hull of the vessel below its waterline, a spar having a hollow trunnion part open at one end journaled in the bearing frame to move about the axis and having a hollow tapered outboard fin part, a web extending traversely of the spar axis in the outboard hollow portion thereof, a rigid arm extending along the axis of the hollow spar connected at one end to the web, a removable plate fixedly mounted within said hollow trunnion part, signal generating means having a part fixed to said plate and a part connected to the other end of the rigid arm, a spar drive motor having a removable casing and rotor connected to the other end of the frame as a cantilever member supporting the rotor within the hollow trunnion part of the spar, and a coupling between the rotor and trunnion part permitting removal of the motor and the plate with the part fixed thereto from the inboard open end of the spar trunnion part.

8. The combination claimed in claim 7, in which the coupling is connected to the trunnion through the removable plate.

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