March 26, 1957 H. J. NICHOLS 2,786,539

CONTROLLABLE-PITCH PROPELLER SYSTEM

Filed Nov. 26, 1948 4 Sheets-Sheet 1

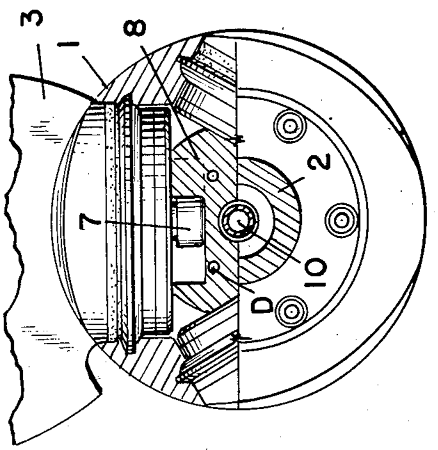

FIG. II

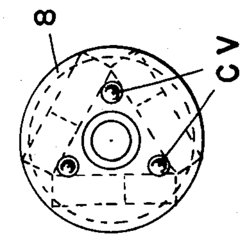

FIG. IV

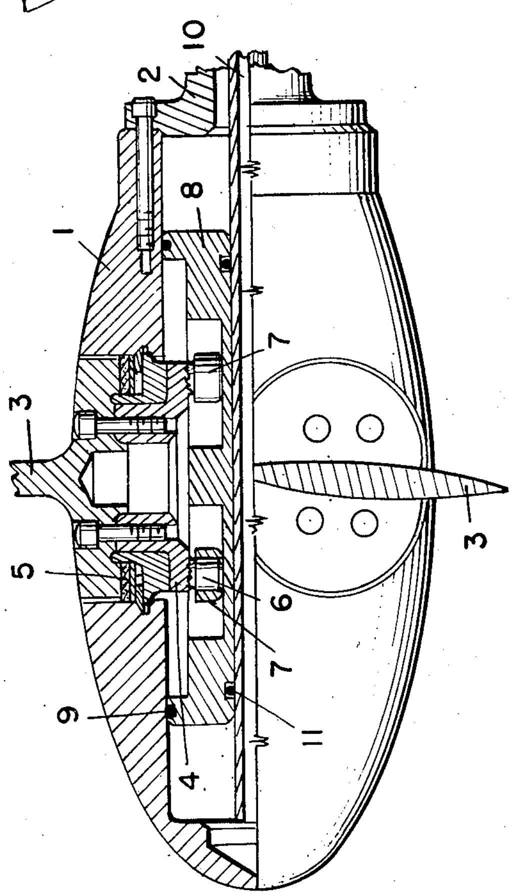

FIG. I

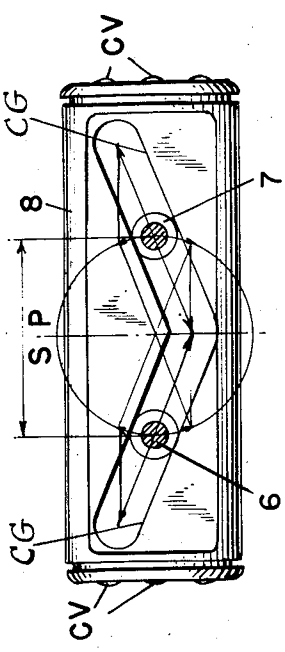

FIG. III

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CONTROLLABLE-PITCH PROPELLER SYSTEM

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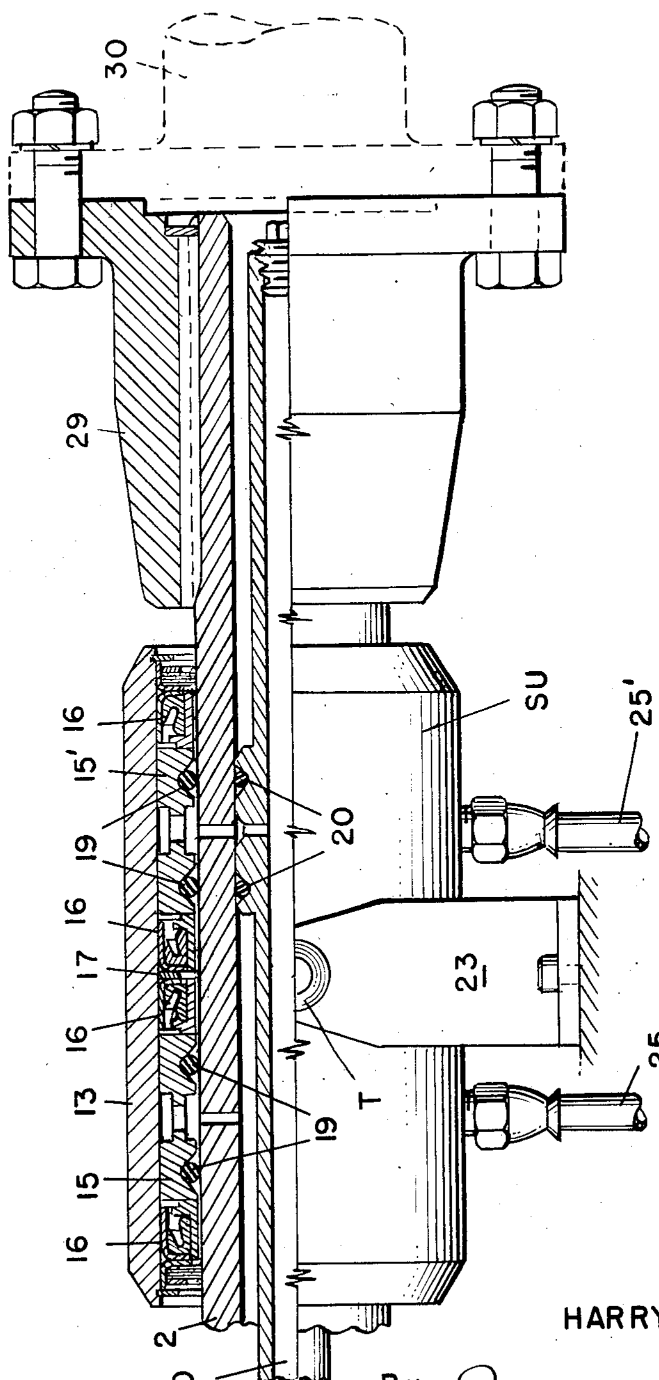
FIG. V



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CONTROLLABLE-PITCH PROPELLER SYSTEM

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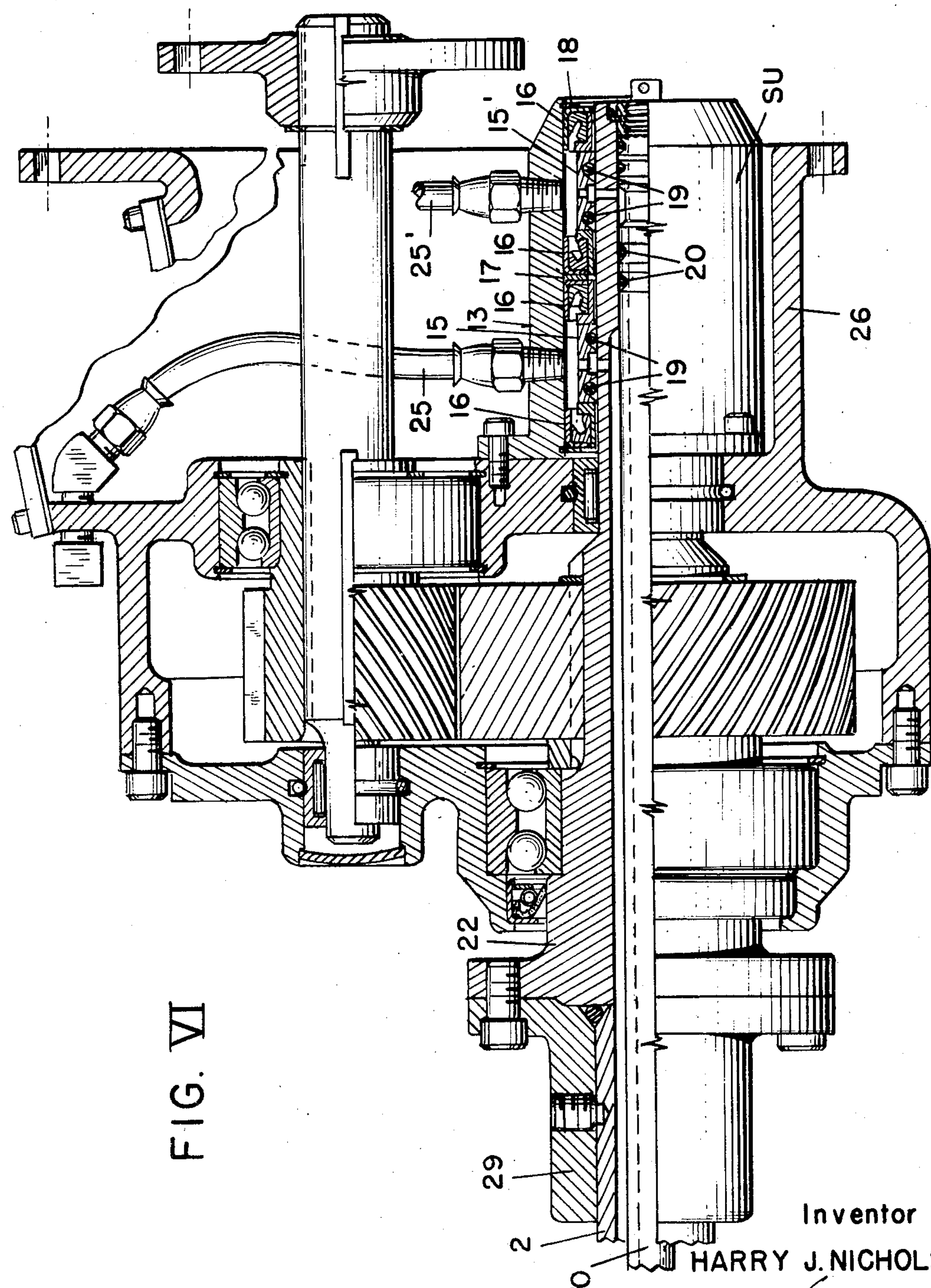

FIG. VI

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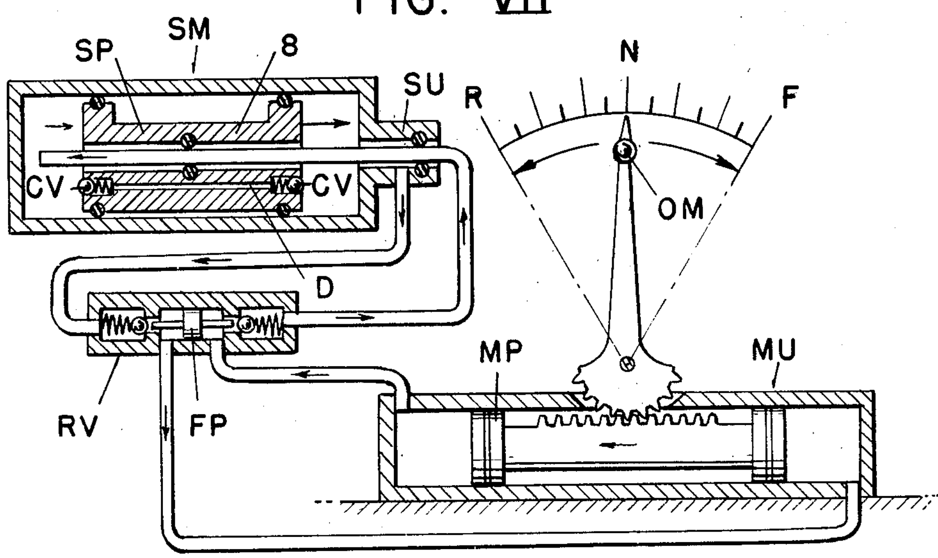
FIG. VII



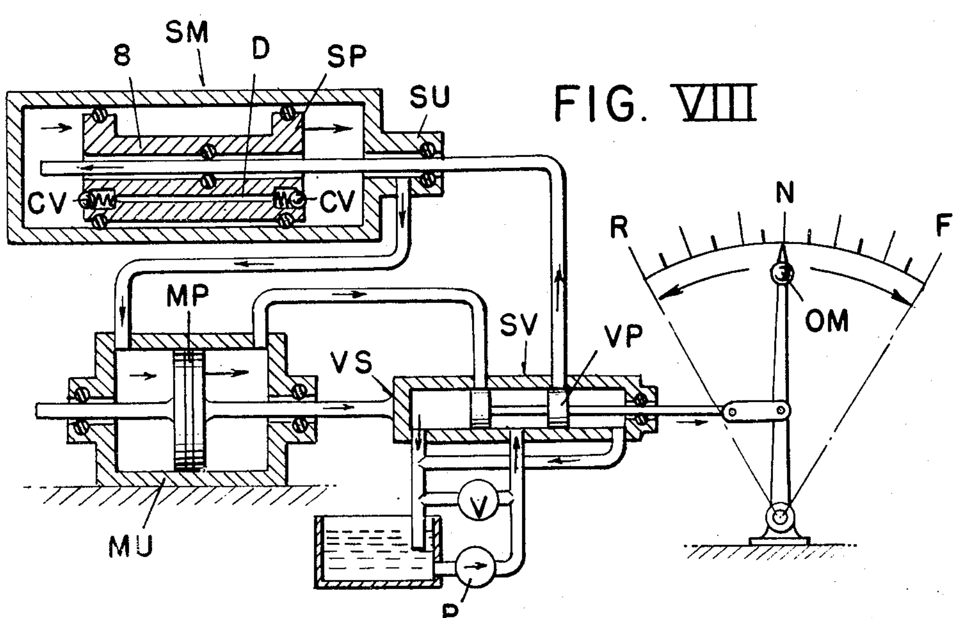


FIG. VIII

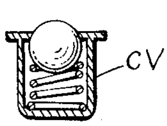


FIG. IX

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CONTROLLABLE-PITCH PROPELLER SYSTEM

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Application November 26, 1948, Serial No. 62,017

7 Claims. (Cl. 170—160.32)

This invention relates to a controllable-pitch propeller system, and more particularly to an hydraulically operated propeller system for marine applications.

The prior art discloses numerous propeller systems for marine use wherein the power for changing the pitch of the blades is transmitted by hydraulic means. Such systems of the prior art, while having been successful to a limited extent in certain cases, have been characterized by the complexity of the mechanisms and hydraulic apparatus which have been employed, and this complexity has been one of the main drawbacks which has prevented extensive adoption of such systems. A main object of the present invention is therefore to overcome this and other drawbacks and limitations of the prior art by providing a hydraulic marine propeller system characterized by the utmost simplicity of mechanism and apparatus, reliability and low cost.

A further object is the provision of a hydraulic marine propeller system readily adaptable to a wide range of applications, comprising generally a system which can be manually operated in the case of propellers for small craft, and manually controlled but power operated in the case of propellers for large vessels.

A further object is to provide a novel remote control system for hydraulic marine propellers, including automatic pitch indicator means and automatic synchronizing means.

In the accompanying drawings, in which like reference numerals and symbols are used to designate similar parts throughout, there is illustrated a suitable mechanical embodiment for the purpose of disclosing the invention. The drawings, however, are not to be taken as limiting the invention, the scope of which is to be measured entirely by the scope of the appended claims.

Fig. I is a longitudinal view in half-section of a three bladed propeller assembly according to the invention.

Fig. II is a right view in half-section of the assembly shown in Fig. I.

Figs. III and IV are details showing top and right end views, respectively, of the cam piston of the propeller assembly.

Fig. V is a longitudinal view in half-section of the inboard end of the propeller shaft and the hydraulic fluid sealing unit constituting part of the invention.

Fig. VI is a longitudinal view in section of a transmission unit showing another embodiment of the sealing unit.

Fig. VII is a schematic diagram illustrating the principle of operation and major functional elements of the system of the invention when adapted for manual operation.

Fig. VIII is a similar schematic diagram similarly illustrating the system of the invention when adapted for power operation.

Fig. IX is a detail view of one type of calibrating valve suitable for synchronizing purposes.

The system of the invention comprises generally the propeller assembly as shown in Figs. I–II, a tubular propeller shaft and a hydraulic fluid conduit mounted coaxially in the propeller shaft thereby to connect the hydraulic apparatus operatively to the propeller assembly; a fluid transfer sealing unit for connecting hydraulic working fluid to the propeller shaft and conduit as illustrated in Figs. V and VI; and hydraulic apparatus and remote control means as illustrated in Figs. VI and VII.

The propeller assembly

Referring now to Figs. I and II, the propeller assembly consists of a one-piece hub **1**, having a blind axial cylindrical bore and radial blade sockets, secured tightly to the propeller shaft **2** so as to provide a closed chamber; blades **3** mounted rotatably in the blade sockets so that they can be turned each about its own spindle, and a compact, hydraulically actuated mechanical movement for turning the blades axially in unison so as to vary their pitch.

The blades are each provided with a circular boss and are detachably mounted for rotation in the blade sockets by means of a demountable flanged journal **4** and a combination radial and thrust bearing and fluid seal **5**, as shown. Each journal is provided with a pair of diametral crank pins **6**, i. e. located at the ends of a diameter having its center on the axis of the journal, each crank pin being fitted with a sleeve roller **7** to minimize friction and wear. The hydraulically actuated mechanical movement for turning the blades in their bearings consists of these crank pins and an axially displaceable combined cam and piston **8**, herein termed the servo piston, mounted coaxially slidable in the bore of the hub and having lateral faces, one for each blade; each lateral face having cut therein oppositely inclined curved grooves CG, herein termed cam grooves, in which the pair of crank pins engaging therewith are forced to move as followers upon axial translation of the piston (see Figs. III and IV). The displacement of the servo piston is continuously controlled by hydraulic means, presently to be described, which in effect measures the volumetric displacement of the servo piston.

The cam grooves apply a torque-couple to the blades by means of the pairs of diametral crank-pins upon axial movement of the piston, and are preferably of special curvature so as to cause uniform angular displacement of the blades in direct proportion to such movement. More specifically, the curvatures of the cam grooves are conjugate trochoids, as more fully explained in my copending application Serial No. 770,640, filed August 26, 1947. This mechanical movement provides a substantial mechanical advantage due to cam action, and this mechanical advantage, combined with the torque-couple action, enables the blades to be turned with a minimum of working force and of binding action of the journals in their bearings. This mechanical movement is also "self-locking"; that is, the blades are automatically locked in any position of adjustment. This construction thus contributes importantly to the high efficiency of the system of the invention.

The circular ends of the servo piston are provided with one or more annular grooves and hydraulic packings **9** of suitable commercial type to prevent passage of fluid between the piston and the cylinder walls. The preferred form of packing is that commonly called an O-ring, which may be of any suitable resilient material. Fluid pressure wedges the O-ring packing tighter in its groove, thus ensuring a reliable fluid seal. The preferred hydraulic fluid is engine lubricating oil, altho other suitable hydraulic fluids may be used. Oil under pressure is led to the inboard end of the piston by the tubular propeller shaft, while oil under pressure is led to the outboard end of the servo piston by axial conduit **10**, the latter also being provided with one or more annular packings **11**.

The servo piston is also provided with one or more calibrating valves CV, illustrated in Fig. IX as of spring-loaded ball check type altho spring-loaded pin check valves or other suitable types may be employed instead; which valves are connected by longitudinal ducts D in the piston, as indicated in Fig. VII. Each valve is assembled in the end of the servo piston so that the movable member of the valve, say the ball, projects slightly beyond the face of the piston, so as to be engaged by the cylinder end towards which the piston moves and thereby actuated when the servo piston moves to either of its extreme positions. Thus, as the servo piston approaches one or the other end of its stroke, a passage is opened through it, permitting oil to by-pass from the pressure to the exhaust end of that piston, thereby limiting its stroke. This same by-passing action synchronizes the stroke of the slave servo piston with that of the master piston, as described hereinafter. When oil under pressure is first introduced into the hydraulic system, the valve means by-pass any trapped air around the servo piston, permitting air to be eliminated from the hydraulic system. The valve means provided thus serve the combined functions of a pitch-limit device, an automatic synchronizing device, and means for bleeding air from the hydraulic system and replenishing oil lost by leakage, etc., but for brevity they are hereinafter referred to as calibrating valves.

A suitable supply of lubricant for the mechanical movement and the blade bearings is provided in the space between the piston and the blade mountings. This supply of lubricant does not have to be renewed or replaced except when the hub assembly is dissembled.

From the above description it will be observed that when oil under pressure is introduced into the interior of the hollow shaft **2**, or alternatively into conduit **10**, it will act to move piston **8**, thus to change the propeller pitch.

The fluid transfer sealing unit

Referring now to Fig. V, which shows one embodiment of the fluid transfer sealing unit SU of the invention, located near the coupling **29** which couples the propeller shaft **2** to the engine shaft **30**, whereby pressure oil is introduced into the hollow of shaft **2** and into conduit **10**. This unit comprises generally a body **13**, here having the form of a sleeve, in the smooth bore of which is assembled two distributor rings **15, 15'**, and four unitary face seals **16**, as shown. These face seals are preferably of differential pressure type in which the seal face is pressed against the smooth edge of the adjacent distributor ring by oil pressure, in well-known manner. The face seals here shown consists of a seal body, packing ring, and seal face, but other commercial seals of somewhat different construction may be used. The expandable packing ring, of resilient material, prevents passage of oil between the seal face and the seal body, while each seal body is fitted in the bore of the body **13** under compression and thus prevents passage of oil therebetween. The middle pair of seals are held slightly apart by a washer **17**, to ensure free working of the seal faces, which it will be observed clear the shaft slightly, and are axially slidable in the seal body. The end seals are retained in position in the body **13** by retainer rings. The distributor rings are held tightly on the propeller shaft **2** by means of O-ring packings **19**, each assembled in a V-groove. As the oil pressure increases, the O-rings wedge more tightly between the sloping sides of their V-grooves and the shaft, in well-known manner. Thus the distributor rings are caused to grip the shaft with increasing pressure as the oil pressure increases. The distributor rings have annular grooves and radial holes, as shown, permitting free passage of oil from the outer to inner peripheries thereof. The propeller shaft **2** is provided with two sets of small radial ducts to pass fluid from the inner grooves of the respective distributor rings into the interior of that shaft. Conduit **10** is provided with an enlarged portion having three V-grooves, the outer of which grooves are fitted with O-ring packings **20**. Radial ducts lead from the inner groove to the interior of conduit **10**, which latter is plugged tightly at the inboard end. External conduits **25, 25'** conduct pressure oil from an external source into the interior of the body opposite the distributor rings **15, 15'** respectively.

From the foregoing description, it will be observed that pressure oil from external conduit **25** is passed by the distributor ring **15** and associated ducts into the interior of the propeller shaft **2**; while pressure oil from conduit **25'** is passed by distributor ring **15'** and associated ducts into conduit **10**. This same oil lubricates all the rubbing surfaces of the sealing unit, ensuring continuous automatic lubrication, so long as oil is supplied to the unit.

The distributor rings, which are preferably of hardened steel, are a rotary fit in body **13**, which is provided with means, such as trunnions T (one being shown) to prevent rotation of the seal unit. The trunnions are preferably loosely restrained by stationary supporting brackets **23** (one being shown) so that the seal unit floats on the shaft, thereby to enable the seal unit to ride easily on and with the shaft, even if the latter runs somewhat eccentric. This is an important practical feature of the construction of the invention, which avoids overheating due to friction, and wear or scoring of the shaft; thus overcoming a main drawback which has heretofore been experienced with propeller shaft sealing devices of the prior art. Moreover, the propeller shaft does not need to be made of a hard or hardened metal, permitting a nonferrous shaft to be used if preferred.

Referring now to Fig. VI, the main structure there shown is a reduction gear transmission unit of a type commonly used with gasoline and diesel marine engines of medium power, and hence does not require detailed description. The feature related particularly to the present invention is that the propeller shaft **2** is tightly coupled to a hollow tail shaft **22**, rotatable in stationary bearings mounted in the transmission unit housing **26**, as shown. The conduit **10** extends thru the hollow tail shaft into the inner compartment of the housing. The body **13** of sealing unit SU is in this case fixed to the adjacent wall; and the distributor rings **15, 15'**, are in contact only with the tail shaft **22** and the face seals **16**.

Because of the similarity of the remaining parts of this sealing unit to that shown in Fig. V, it is believed that its construction and operation will be understood from the description of Fig. V and the showing of Fig. VI.

Pitch control system

The foregoing description related to the propeller and pitch actuating means, and the relation of these to the pitch control system will now be considered.

Referring now to Fig. VII which shows schematically the system of the invention adapted for manual operation, for use on small craft. The apparatus indicated schematically, in addition to that already described in detail, is of well-known commercial type, and hence need not be described in detail. The actuator of the propeller mechanism is for brevity referred to generally as the servomotor SM, and the cam piston member **8** thereof as the servo piston SP. Pressure fluid is delivered to and received from the servomotor SM by motor unit MU which may take the form of a single cylinder, double-acting hand pump of well-known type, as indicated, the piston of this pump being termed the motor piston MP. The main requirements for the motor unit MU in this case are that the fluid capacity must substantially equal the volume of fluid displaced by the servo piston SP during its working stroke, the motor piston MP should work fluid tight, and the leverage of the pump handle must be sufficient to produce the required working pressure when manually operated.

A fluid locking valve RV, commonly termed a "rachet valve," is connected in the conduits between the motor unit MU and servo motor SM for purposes of holding pressure on both sides of the servo piston SP, as explained hereinafter; thereby preventing any change in the pitch setting due to the reaction of the blades. The system shown may have associated means of known type, not shown, for accommodating thermal expansion of the fluid.

The operation of the system is as follows: All the moving parts of the system are assumed to be at rest in the mid or neutral N position. Both check valves of the rachet valve RV are closed, locking the fluid in the servo motor SM against displacement due to any reaction force on the servo piston SP.

Assuming that operating member OM, in this case the pump handle, is moved to the right towards the F or forward position, pressure fluid will be displaced (as indicated by the arrows) from the left chamber of the motor unit MU and will first actuate the floating plunger FP of the rachet valve RV to open the left check valve thereof, thus permitting the previously locked fluid to be exhausted from the right chamber of the servo motor SM into the right chamber of the motor unit MU. Servo piston SP will move in proportion to the volume of fluid displaced by the motor piston MP as the operating member OM is moved; and the propeller pitch will therefore be changed in proportion to the movement of the operating member. When the operating member is released, back pressure from the servo motor forces the check valves of the rachet valve into closed position, thus trapping fluid on both sides of the servo piston as before.

When the operating handle is moved to the left towards the R or reverse position, the foregoing movements are reversed in direction, resulting in a reverse change of pitch. It is thus evident that the movements of the operating member, motor piston, and servo piston are directly related, and if these movements be synchronized, the position of the operating member will automatically indicate the propeller pitch. In this system, the operating member OM can only be moved as the pitch is changed.

However, in each cycle of operations as above described, a minute amount of fluid may pass from one side of the system to the other without exact consequent movement of the operating member and eventually synchronism will be lost. The calibrating valves CV in the servo piston SP overcome this defect, because whenever the servo piston reaches either end of its predetermined stroke, both check valves are opened and fluid can then pass from one chamber in the hub to the other without moving the servo piston; until the operating member reaches the end of its stroke and is reversed, whereupon the direction of the flow of fluid is reversed and the free check valve is closed. Hence, merely by moving the operating member to one extreme position or the other, the system will be re-synchronized. It should also be observed that with the system described there is no danger to the operator due to a possible "kick-back" of the blades when the pitch is reversed under load. In such event the rachet valves would instantly close, preventing further movement of the servo piston.

Referring now to Fig. VIII, the servo control system there shown is adapted for power operation and manual control, as required for large vessels where the force required for changing the pitch may exceed the strength of an operator. In this system, a power source of fluid, symbolized by pump P, supplies pressure fluid to the motor unit MU and servo motor SM under the control of a servo-valve SV which is operated by the operating member OM. In this example, it should be observed that the operating member OM actuates the valve plunger VP, while the valve sleeve VS is actuated by the motor piston MP, as shown.

Assuming as before that the operating member OM is moved toward the F or forward position, the sequence of movements, as indicated by the arrows will be as follows: The plunger VP of the servo-valve SV on moving to the right will pass pressure fluid from the pump P to the left chamber of the servo motor SM, and exhaust fluid from the right chamber of the motor unit MU. The differential pressure on the servo piston SP causes it to move to the right, changing the pitch; and to displace fluid into the left chamber of the motor unit MU, causing the motor piston MP to move to the right and moving valve sleeve VS in the same direction as the plunger moved. This follow-up movement will continue until the servo-valve ports are closed, whereupon movement of the fluid and pistons cease. Step-by-step analysis will show that the servo and motor pistons move in proportion to the fluid displaced, as before, and that the pistons accordingly move in synchronism. It should be observed, however, that in this example the operating member OM can be moved independently of the pitch change, but if the system is synchronized its final or rest position will indicate the pitch of the blades, as before.

Detailed analysis will show, however, that as before there may be a minute loss of unregistered fluid for each operation of the system. Also, as before, this defect is overcome by the calibrating valves CV in the servo piston, and in the same manner; that is, by moving the operating member OM to either extreme position, the system will be re-synchronized.

While there has been illustrated and described particular preferred embodiments of the system of the invention, it is to be understood that the invention is not limited to these particular embodiments so illustrated and described, but that such changes in the details and arrangement of elements of the system may be resorted to as come within the scope of the appended claims.

Having now described the invention so that others skilled in the art may clearly understand same, what it is desired to secure by Letters Patent is set forth in the claims as follows:

1. A controllable pitch marine propeller system comprising, in combination: a hollow propeller shaft; a hub fixed tightly to said shaft and carrying blades journaled in said hub for pitch changing movement; mechanism within said hub for turning said blades axially including a double-acting hydraulic servo-motor having a cylinder with two chambers for liquid and a servo piston actuated in opposite directions by the pressure of liquid in the two chambers, and a mechanical movement for applying relative movement of said servo piston so as to turn said blades in unison about their axes; calibrating valve means actuated by said servo piston at either end of its stroke; a double-acting hydraulic motor having two chambers for liquid and a relatively movable motor member actuated in opposite directions by the pressure of liquid in the two chambers; a power source of pressure liquid; a control valve for said liquid having a movable valve member and two valve ports; a hydraulic connection between one of said valve ports and one chamber of said servo motor, a second hydraulic connection between the other of said valve ports and one chamber of said hydraulic motor, and a third hydraulic connection between the other chambers of said motors, whereby said motors are reversibly actuated in series by said control valve; a position control member; linkage means between said control member and said movable valve member whereby direct motion is imparted to said valve member upon actuation of said control member; a connection between said motor member and said control valve whereby follow-up motion is imparted to said control valve upon actuation of said motor member by liquid pressure; and means including said calibrating valve means for establishing and maintaining a predetermined coordination of the position of said servo piston with respect to that of said position control member, whereby the rest position of said control member controls and indicates the pitch of said blades.

2. A controllable pitch marine propeller system comprising, in combination: a hollow propeller shaft; a hub fixed tightly to said shaft and carrying blades journalled in said hub for pitch changing movement; mechanism

within said hub for turning said blades axially including a double-acting hydraulic servo motor having a liquid displaceable servo piston and a mechanical movement for turning said blades upon displacement of said servo piston; means for supplying a controlled quantity of pressure liquid to said servo motor, thereby to control the displacement of said servo piston including a power source of pressure liquid, a control valve for said liquid, a double acting hydraulic motor having a liquid displaceable motor member and hydraulically connected to said servo motor and said control valve so that said motors are reversibly actuated in series by said control valve, a movable position control member, linkage means connecting said control member and said motor member to said control valve whereby direct actuating motion is transmitted to the control valve upon movement of the control member and follow-up actuating motion is transmitted to the control valve upon displacement of the motor member, and automatic calibrating valve means operated by said servo piston for establishing and maintaining a predetermined coordination of the position of said servo piston with respect to that of said control member, whereby said control member precisely controls the pitch of said blades.

3. In a controllable pitch marine propeller system including blades mounted for pitch changing movements, in combination, fluid actuated blade moving mechanism including a fluid displaceable servo piston, means including a hydraulic motor cylinder having a motor piston for supplying a controlled quantity of fluid under pressure to displace said servo piston in determinable degree, a movable pitch controlling and indicating member, a power source of pressure fluid, valve means for controlling the supply of pressure fluid from said source either to said servo piston or to said motor piston and operatively connected to said member and said motor piston so as to be responsive to the differential movements thereof, and automatic calibrating valve means actuated by said servo piston for synchronizing the movements of said servo piston with those of said motor piston and said member, whereby the position of said member at the end of a pitch changing cycle indicates the pitch of said propeller blades.

4. A controllable pitch propeller system having, in combination, blades mounted in a hub for pitch changing movements, blade moving mechanism including a servo motor having a fluid displaceable servo piston operatively mounted in said hub, a motor unit having a fluid displaceable motor piston, a power source of pressure fluid, a servo valve having a pair of independently movable valve parts arranged to control the supply of fluid from said source to either said servo motor or said motor unit, one of said valve parts being movable by said motor piston, an operating member connected to move the other of said valve parts, and means including a pair of automatic synchronizing valves carried by said servo piston for synchronizing the movements of said servo piston with those of said operating member; whereby the rest position of said operating member automatically indicates the pitch of the blades.

5. A combined hydraulic servo control and pitch indicating system for a controllable pitch propeller, including a double-acting cylinder and having a fluid displaceable servo-piston operatively connected to change the pitch of its blades comprising, in combination, hydraulic apparatus for supplying hydraulic fluid controlled as to quantity to said cylinder thereby to displace said servo-piston in determinable degree; said mechanism including a combined pitch control and pitch indicating master member; a fluid motor hydraulically connected in series with said cylinder and a control valve actuated differentially by said master member and said fluid motor, and automatic calibrating valve means operatively associated with said servo-piston and actuable by an end of said cylinder upon the servo-piston approaching the latter at either end of its stroke for coordinating the movements of said servo piston with said master member, whereby the position of said master member when at rest automatically indicates the pitch of said propeller.

6. In a controllable pitch propeller system including blades turnable about their axes, the combination comprising: a hydraulic servo-motor including a servo-piston displaceable by fluid under pressure and connected to turn said blades; means for supplying a controlled quantity of fluid under pressure to said servo-motor so as to control precisely the displacement of said servo piston, said means including a double-acting hydraulic cylinder hydraulically connected in series with said servo-motor and having a volumetric capacity substantially equal to the volume of fluid displaced by said servo-piston and a motor piston displaceable in said cylinder by said fluid; a movable remote pitch controlling and indicating member; a power source of pressure fluid; servo-valve means for controlling quantitatively the supply of pressure fluid from said power source either to said servo-motor or to said cylinder and connected so as to be actuated differentially by said pitch controlling and indicating member and said motor piston; and automatic calibrating valve means in and actuated by said servo-piston for synchronizing the movements of said pistons by regulating the quantity of fluid interconnecting said pistons.

7. A controllable pitch propeller system having in combination: blades mounted in a hub for pitch changing movements; blade moving mechanism including a servo-motor having a fluid displaceable servo-piston operatively mounted in said hub; means including a stationary motor unit having a fluid displaceable motor piston working therein for supplying a controlled quantity of fluid under pressure sufficient to displace said servo-piston; valve means having two independently movable valve parts for controlling the supply of pressure fluid to said servo-piston and to said motor piston, one movable part being under the control of said motor piston; a movable pitch controlling and indicating member arranged to control the second movable part of said valve means, and automatic calibrating valve means actuated by said servo-piston for synchronizing the movements of said servo-piston, said motor piston and said member; whereby the position of said member when the aforesaid movable elements of said system come to rest indicates the pitch of said blades.

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