April 23, 1963 H. J. NICHOLS 3,086,595

HYDRAULIC CONTROLLABLE PITCH PROPELLER SYSTEM

Filed Nov. 23, 1959 4 Sheets-Sheet 1

FIG. I

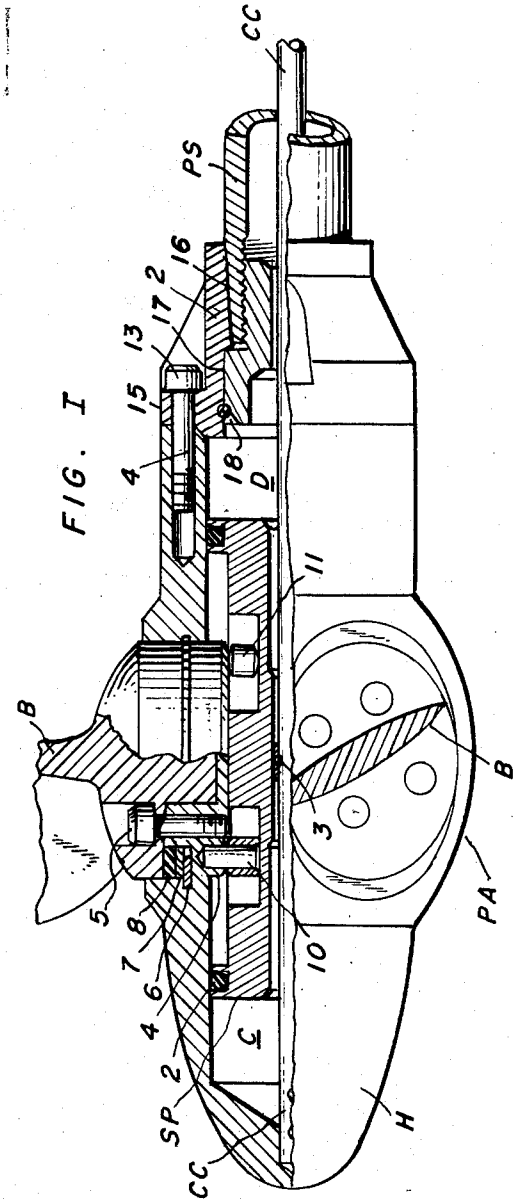
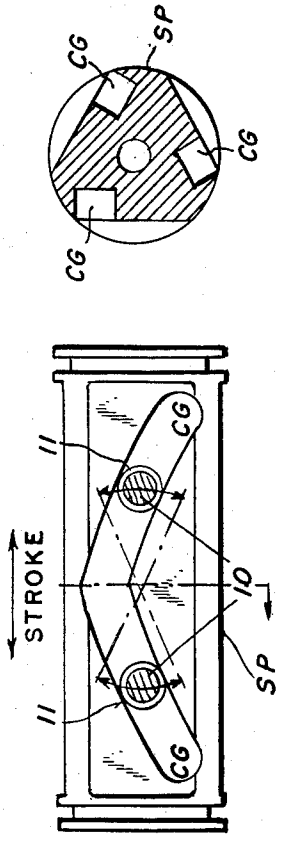


FIG. II



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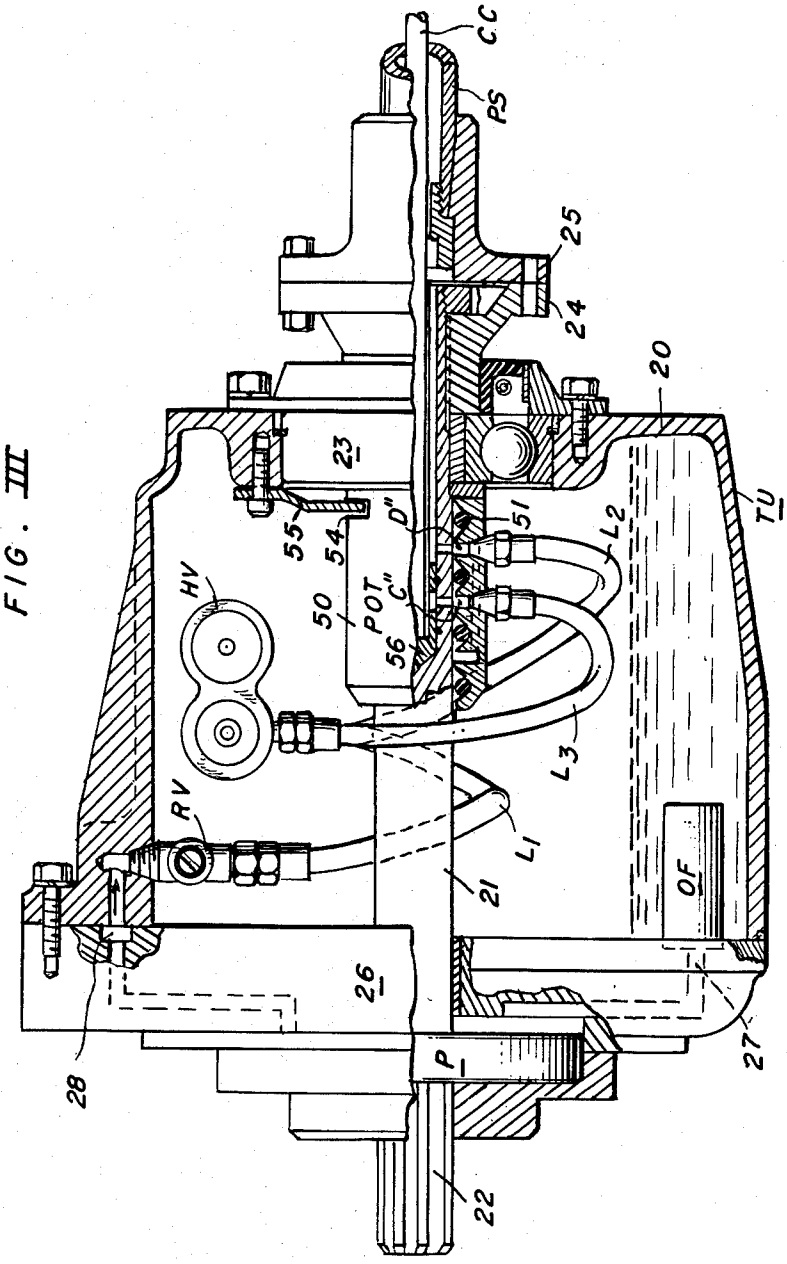
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HYDRAULIC CONTROLLABLE PITCH PROPELLER SYSTEM

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FIG. III



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HYDRAULIC CONTROLLABLE PITCH PROPELLER SYSTEM

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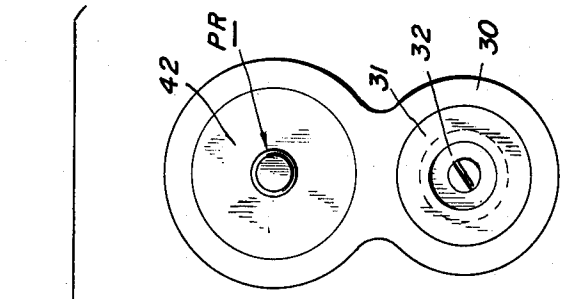


FIG. IV

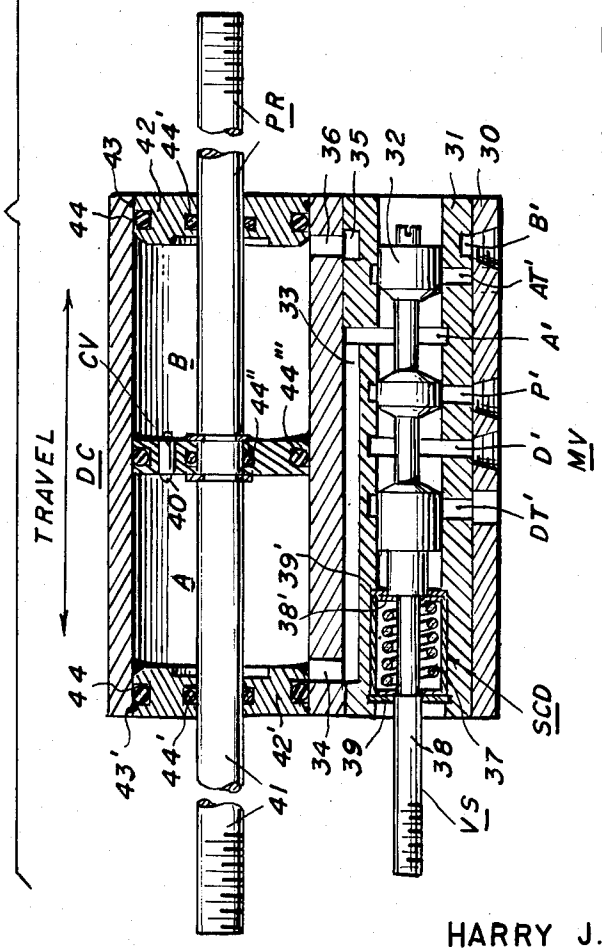
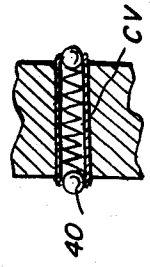


FIG. IV A



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HYDRAULIC CONTROLLABLE PITCH PROPELLER SYSTEM

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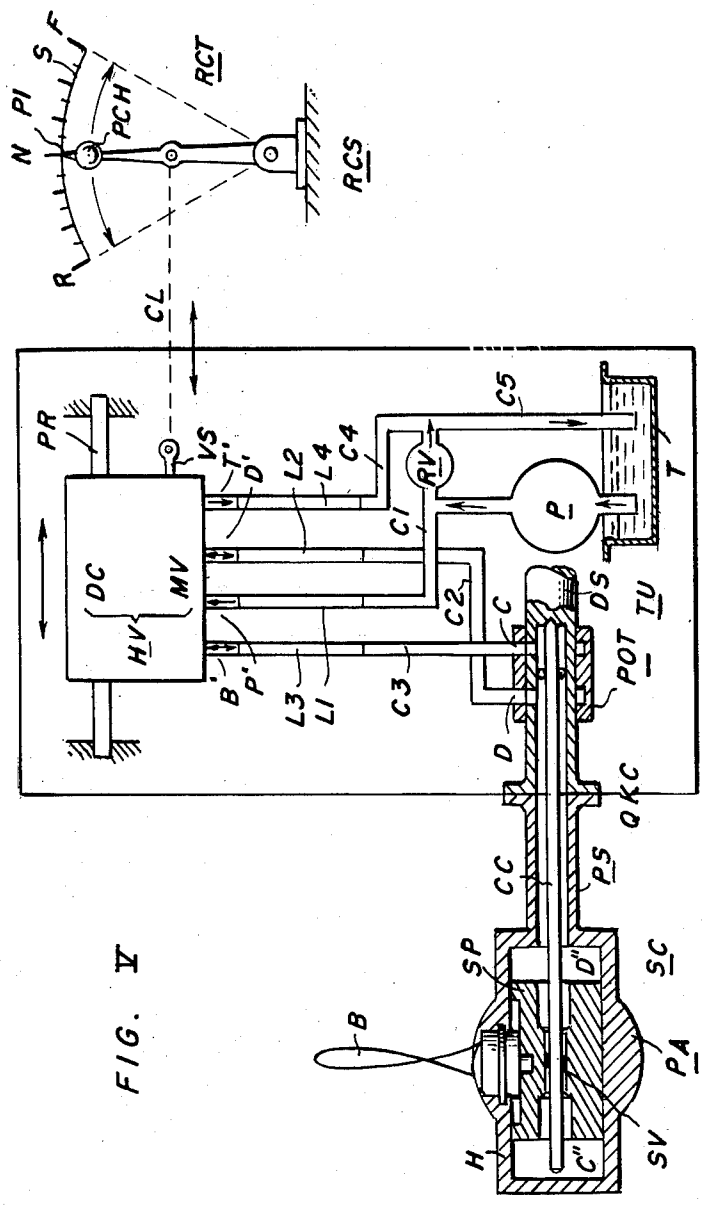


FIG. V

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United States Patent Office 3,086,595
Patented Apr. 23, 1963

3,086,595
HYDRAULIC CONTROLLABLE PITCH PROPELLER SYSTEM

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Filed Nov. 23, 1959, Ser. No. 854,645
19 Claims. (Cl. 170—160.32)

This invention relates to an improved hydraulic controllable pitch propeller system and more particularly to a coordinated hydraulically operated and controlled propeller system for inboard motorboats.

The prior art discloses various propeller systems for marine use wherein the power for changing the pitch of the blades is generated, transmitted and applied by hydraulic means. Such systems of the prior art, while successful to a limited extent in motorship applications, have been characterized by complexity and heavy construction, hence consequent high cost of the mechanisms and hydraulic apparatus which have been employed. A further limitation has been that hydraulically operated propeller systems of relatively small size and high speed, as for example propeller systems for motorboats, were impractical because the hub diameter of the propeller was too large for efficient high speed propulsion; and other mechanical and hydraulic components were too bulky to be accommodated in the extremely limited spaces available in practice. A further drawback of the apparatus of the prior art has been the tendency to imprecise control and unreliable operations, as well as wear and short lift of certain working parts and components.

The main object of the present invention is therefore to overcome these and other limitations and drawbacks of the prior art by providing an improved controllable pitch propeller system and apparatus of ultimate simplicity and compactness, characterized by reliability and ruggedness, ease of installation and lowest overall cost.

A further object is to provide a coordinated marine propeller system controlled and operated by hydraulic power meeting in all respects the rigid technical, practical and economic requirements of fast, small craft with inboard engines such as utility and fishing boats, runabouts, sedans, cruisers, yachts, etc.

Another object is to provide a compact and powerful blade turning movement of adequate angular range, yet adapted to be housed in a propeller hub of relatively small size; which will have a minimum of parts; which will hold the blades rigidly thereby avoiding any possibility of flutter or vibration during operation due to back-lash or elasticity; and which will be virtually self-locking in any position to which it may be set.

Because of the multitude of types and sizes of motorboats, and for economic reasons, remote pitch controls for motorboats must be extremely simple, versatile, inexpensive and easy to install. The amount of transmitted force required for pitch control purposes should be no greater than that required for engine throttle control. Also, many motorboats used for fishing have dual control stations which require duplicate pitch controls at each station. This requires in practice "free" controls which are always unlocked and ready for use. It is also essential that the position of the pitch control handle indicates visually the existing pitch. Since the boat operators are unskilled, the necessary synchronization of the movements of the servo piston with those of the pitch control handle must be established and maintained automatically; and if lost restored automatically.

Moreover, the pitch control system must be quite precise. This can be appreciated from the fact that a small change in pitch angle has a substantial effect on the top speed of a motorboat. For example, a pitch angle change of three degrees in a propeller having a diameter of

twelve inches rotating at 3600 r.p.m. can increase the top boat speed from 28 miles per hour to 33 miles per hour; provided of course that the propulsion engine has the required reserve power. For these and other reasons, the pitch control systems of the prior art have failed to meet the technical and economic requirements of motorboats, ruling out the adoption of prior hydraulic controllable pitch propellers for motorboats.

Hence another object is to provide a novel hydraulic remote pitch control system, including automatic pitch indicating and automatic synchronizing, which is precise in operation, yet simple and inexpensive, and easy to install.

A further object is to provide a pitch control system with a free master pitch control member which not only controls but also automatically follows and indicates the pitch angle of the propeller blades.

A further object is to provide automatic means for establishing and maintaining synchronism of the movements of the servo piston in the propeller hub with the movements of the master pitch control member.

It is well known that the clutch and reverse gear unit usually employed on marine propulsion engines of internal combustion type to stop and reverse the rotation of the propeller represents a disproportionate part of the over-all cost, weight, size and complexity as compared to the engine proper; and this is particularly true in the case of inboard engines for motorboats. Moreover, the clutch and reverse gear are functionally useful only during a few percent of the engine operating hours and contribute nothing to propulsion efficiency but rather continuously absorb unused power, and are therefore highly uneconomical in relation to their limited useful functions. It is therefore a further object of this invention to provide, as a sub-combination forming part of the invention, a simple transmission unit closely coordinated with the controllable pitch propeller and the pitch controls, particularly adapted for use with marine engines of the inboard class in place of, or as a replacement for, the ordinary clutch and reverse gear unit; which unit will also mount and house a source of hydraulic power and quantitative hydraulic means for controlling the movements of the servo piston in the propeller hub.

With these and other objects in view, as well as other advantages incident to the improved construction, the invention consists in various novel features and combinations thereof set forth in the claims with the understanding that the several necessary elements constituting the same may be varied in proportion and arrangement without departing from the nature and scope of the invention as defined in the appended claims.

To enable others skilled in the art to comprehend the underlying features of this invention that they may embody the same by suitable modifications in structure and relation to meet the various practical applications contemplated by the invention, drawings showing a preferred embodiment of the invention form part of this disclosure and in such drawings like characters of reference denote corresponding parts in the several views in which:

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

FIG. II shows top and mid-section views, respectively, of the cam-piston of the propeller assembly of FIG. I.

FIG. III is a longitudinal sectional view showing salient features of one species of transmission unit constituting a part of the invention.

FIG. IV is a sectional and end view of a novel hydraulic amplifier device constituting a distinctive part of the invention.

FIG. V is a schematic diagram illustrating the general

principle of operation and functional relations of the major elements of the system of the invention.

General Description

The coordinated system of the invention considered as a whole comprises a unitary propeller assembly PA having an integral hub constituting a double-acting hydraulic cylinder with coaxial rodless servo piston SP, preferably as shown in FIG. I; a transmission unit TU such as shown in FIG. III with hydraulic apparatus including a novel hydramp valve HV for controlling the application of hydraulic fluid to servo piston SP; a tubular propeller shaft PS with a coaxial conduit CC which operatively connects the transmission unit to the propeller assembly; and remote pitch controls, including a pitch control handle PCH, of light duty, commercial type which enables the operator to control the pitch at will from any convenient remote control station RCS. The system as a whole constitutes an automatic, hydraulic powered servo system of closed-cycle type.

The Propeller Assembly

Referring now to FIGS. I and II, the preferred propeller assembly PA consists of a one-piece hub H, having a blind axial cylindrical bore and radial blade sockets fastened tightly to tubular propeller shaft PS by special means so as to provide a tight driving connection therewith; propeller blades B each secured rotatably in a radial blade socket, so that they can be turned each about its own axis; and a unique hydraulically operated mechanical movement within the hub bore for turning the blades axially in unison within a certain angular range, thereby to vary their pitch.

Each blade B has a circular boss which is detachably mounted in its socket by being fastened to a quickly demountable flanged journal **4** by means of multiple cap screws **5**. Each blade boss and journal fit into mating bearing surfaces in its socket, each journal being rotatably secured outwardly of its flange by means of a removable retainer ring **6** snapped into an internal circumferential groove in its socket. A plain washer **7** is assembled on top of retainer ring **6** and a ring gasket **8**, of suitable resilient material, is assembled on top of washer **7**, so that when cap screws **5** are tightened, gasket **8** is put under uniform compression; whereby the blade mountings are effectively sealed against entrance of water into the interior of the hub. Each journal flange has projecting from its inner face a pair of twin diametral crankpins **10**, 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 **11** to eliminate working friction and wear. The hydraulically operated mechanical movement for turning the journals in their bearings consists of the diametral crank pins and an axially disposed, integral combination cam-piston, herein termed servo piston SP, slidable coaxially in the bore of the hub and having sunken lateral faces, one for each blade. Each face has a chevron pair of curved two-edge grooves, herein termed cam grooves CG, in which the diametral crank pins engaging therewith are forced to swing about the journal axis as followers upon axial translation of servo piston SP (see FIG. II): hence servo piston SP also constitutes a multiple, positive-motion face cam.

Pressure oil is conducted to the outboard chamber C of hub H by means of coaxial conduit CC and to the inboard chamber D by the hollow cylindrical passage between conduit CC and the bore of the shaft. The travel of servo piston SP within hub H, which constitutes a double-acting hydraulic cylinder, is continuously controlled by hydraulic power means, presently to be described, which continuously measures the volumetric displacement of servo piston SP and hence its travel.

Upon travel of servo piston SP, the cam grooves CG apply a torque couple to each journal via the diametral crank pins **10**; which grooves are of special curvature so as to cause uniform angular displacement of the journals in direct proportion to the servo piston travel. More specifically, the curvatures of the cam grooves are conjugate trochoids, as more fully explained in my U.S. Patent No. 2,675,084. This mechanical movement thus provides a multiple mechanical advantage due to cam action compounded by torque-couple action, and this mechanical advantage, combine with the relatively large "throw" of the diametral crank pins and high mechanical efficiency, enables the blades to be turned, when under load, with a minimum of hydraulic pressure—the required hydraulic pressure being less than one fourth that of any other known system. Also, the high mechanical advantage of the blade turning movement permits an increased travel of servo piston SP, which is quite advantageous with respect to precision of pitch control, as explained hereinafter. Furthermore, this mechanical movement is also "self-locking," that is the blades are automatically locked at any angle set by servo piston SP. A vital consequence of the self-locking feature is that the hydraulic pressure in the two chambers at the ends of servo piston SP are substantialld balanced when the blades are set, thus eliminating the need for any auxiliary mechanical or hydraulic blade or piston-locking device, as required by hydraulic blade turning systems of the prior art. Moreover, the blades are mechanically retained in set position should the hydraulic pressure be lost, thus eliminating the "crutch" device usually provided for this emergency. Finally, the self-locking action automatically stabilizes the hydraulic servo system, preventing "over-shooting" or "hunting" during pitch-changing action. Thus, it is evident that the unique blade turning movement is a vital feature of the entire system of the present invention, and contributes importantly to its high efficiency.

The circular ends of servo piston SP are provided with circumferential grooves and soft piston rings **2** of suitable commercial type, such as resilient O-rings, to prevent leakage of pressure oil along that piston. Servo piston SP has an open axial bore counterbored somewhat at both ends, while conduit CC is provided with a grooved sleeve carrying a small sealing-ring **3**, as disclosed in FIG. I; this combination of parts constituting the servo piston synchro-valve SV. The construction and arrangement of parts provide an automatic sleeve valve with fixed spindle, open only at the extreme travels of servo piston SP; the multiple functions of this valve being explained hereinafter in connection with the operation of the entire system.

A suitable supply of lubricant (say heavy oil) for the mechanical movement and blade bearings is provided in the void space between servo piston SP, the hub bore and the blade mountings. This supply of lubricant does not need to be renewed or replaced during normal operations. The void space within the hub does not vary during the stroke of servo piston SP; thus avoiding any internal pumping action, such as has complicated the sealing and lubrication of certain controllable pitch propellers of the prior art.

From the above description it will be observed that when oil under sufficient pressure is introduced into the bore of tubular propeller shaft PS, or alternatively into coaxial conduit CC, it will act to move servo piston SP in opposite directions, thus to vary the pitch angle of the propeller accordingly. Also, that when servo piston SP reaches either end of its travel, a passage through that piston is automatically opened by synchro-valve SV. Thus, hub H, servo piston SP and synchro-valve SV constitute a double-acting hydraulic servo motor with integral automatic fluid passing and synchronizing means.

The Transmission Unit

Referring now to FIG. III, which shows one species of transmission unit TU suitable for use in the system of the invention, the main structure of the transmission unit,

adapted for high-speed gasoline and diesel marine engines of direct drive type, is a one-piece hollow conical housing **20** adapted to be detachably fastened by multiple cap screws to the driving end of an engine (not shown) in place of the usual clutch and reverse gear unit. The drive shaft **21**, having an inboard end portion **22** splined so as to couple freely with the engine crank-shaft coupling (not shown) is mounted rotatably along the axis of housing **20** by suitable means, including main thrust bearing **23**, preferably of ball-bearing or roller-bearing type. The outboard end of drive shaft **21** is preferably splined and carries a tightly fitting driving-flange **24**, fastened in place in usual manner, as shown. A mating driven-flange **25** is fastened tightly on the tapered inboard end of tubular propeller shaft PS, these flanges being fastened tightly together by suitable means, such as multiple machine bolts, as indicated.

An adapter plate **26**, adapted to fit both the housing **20** and the engine structure, is secured in the inboard opening of housing **20** by a series of cap screws in the usual manner. A stationary pressure oil pump P, such as a gear pump of known type, is mounted in the bore of adapter plate **26** and around the splined portion **22** of drive shaft **21**, so as to be driven thereby. Oil pump P is of low pressure type and of comparatively small size and capacity, because only a small quantity of pressure oil is pumped during a pitch changing cycle. Also, because of the efficient blade turning mechanism, the maximum oil pressure required is less than one fourth that of similar hydraulic systems of the prior art. The low oil-pressure feature enables relatively light structures to be used in the hydraulic components, reduces wear and minimizes leakage, hence it contributes to the efficiency and practicality of the entire system.

Adapter plate **26** is provided with suitable passages and ports for conducting oil from the oil intake **27** near the bottom of housing **20** into and out of oil pump P for delivery at the oil outlet **28** near the top of plate **26**. Intake **27** is preferably provided with a small unitary filter OF, and a relief valve RV is always installed at or near the oil outlet from pump P. A relief valve RV is essential because it is most feasible and economical to employ a low capacity, continuously running, constant output pump, such as a gear or vane type pump; but due to the high speed and power of the drive shaft, such pumps are capable of producing dangerously high pressures unless a proper relief valve is provided.

Due to the highly efficient low-pressure hydraulic and mechanical system of the invention, the power absorbed by pressure oil pump P is usually of the order of 0.1% of the shaft horsepower—which power loss is substantially less than that of the customary clutch-reverse gear unit. Hence, the transmission unit TU of the invention does not normally require an oil cooler.

"Myriad-Loc" Quick Keyless Coupling

Hydraulic controllable pitch propeller systems for motorboats present special shafting requirements not met by ordinary shafts and shaft couplings. Due to the mania for speed, pleasure boats are now equipped with super-speed, superpower engines which formerly characterized racing boats; hence propeller shafts must transmit abnormally high torques at abnormally high speeds. Due to corrosion requirements, propeller shafts in practice are made of non-ferrous metals weaker than steel, such as bronze or Monel. Further, shafts for controllable pitch propellers must be hollow with relatively thin walls, which rules out the use of keyed couplings commonly used with solid shafts. By reason of structural limitations, the propeller shaft must be inserted and removed from outside the boat. Moreover, the inboard shaft coupling must be located in the bottom of the boat near the shaft log, thereby adding the handicap of inaccessibility whenever the propeller shaft is coupled to or uncoupled from the engine.

In order to overcome the above mentioned limitations, disadvantages and drawbacks, a novel quickly demountable keyless propeller shaft coupling is utilized in the present invention. The end portions of the propeller shaft PS are tapered—say 1:16 ratio—while the shaft coupling flanges **15, 25** are provided with a complementally tapered bore and a contiguous plain counterbore; also the shaft bore is suitably threaded at the ends. An abrasive lute **16** containing hard granules, such as emery grit, may be evenly coated on one of the tapered surfaces before assembly of the parts. A fitting jack-screw **17**, which here has the form of a socket—head cap screw drilled axially to provide a bore to receive coaxial conduit CC—works in the threaded bore of the propeller shaft and in the counterbore of the flange; the latter having a half-round circumferential groove located near its mouth, this groove being adapted to seat and hold a mating uncoupling thrust ring **18**. After assembly of jack screw **17**, a plain round wire thrust ring **18** is snapped into the mating groove in the flange counterbore. The operation of the device is as follows: To mount, a fitting commercial socket cap-screw wrench is used to tighten jack-screw **17** "wrench tight," thereby drawing the tapered surfaces into forcible contact and embedding the hard granules in those surfaces. To quickly dismount, the same wrench is used to unscrew jack-screw **17** whereupon thrust ring **18** transmits reverse thrust from jack-screw **17** to the flange, thereby breaking loose the tight tapered joint, and thereafter withdrawing the flange from the shaft. For further particulars, reference is made to my co-pending application, Serial No. 370,438, now abandoned.

The Traveling Hydraulic Amplifier Valve

Referring to FIG. IV, the novel hydraulic amplifier valve of the invention, herein termed the "hydramp valve" HV, comprises in general "master valve" MV of directional, spring-centered, five-port, "leaky-center" type; and double-acting traveling "duplicating cylinder" DC; both combined into a unitary structure by integral valve body **30**, which has two parallel longitudinal bores, as shown. Master valve MV comprises a heavy-walled cylindrical sleeve **31** fitted tightly into one bore of valve body **30**, a closely fitted valve spool **32** slidable axially in the bore of sleeve **31**, and a spring centering device SCD. The main functions of sleeve **31** are to facilitate construction and to simplify the passages and ports of the hydramp valve; and also to permit external lines to be connected at various locations and angles; thus providing a multi-port valve construction of unusual versatility, as well as of ultimate simplicity. Sleeve **31** has five cross-passages constituting valve ports, a longitudinal passage **33**, a circumferential passage **35**, and three or four external ports, arranged generally as shown. The external ports, providing connections to the valve ports and circumferential passage **35**, can be located in valve body **30** at any angular position not blocked by the cylinder. Longitudinal passage **33** and cross duct **34** provide an internal connection CA between valve port A' and chamber A of duplicating cylinder DC, while an internal connection with chamber B is provided by cross-duct **36** in valve body **30**, thence via circumferential passage **35** to port B' as shown.

For purposes of controlling oil flow, master valve MV has five valve ports; namely an inlet or pressure port P'; distribution ports A' and D' connected to chamber A of duplicating cylinder DC and chamber D of servo motor SM, respectively; and two exhaust ports which release the exhaust oil discharged via port A' or port D' during pitch changing operations for return to tank T, hence called port AT' and port DT'. In the illustrated applications, since only a small quantity of pressure oil is utilized during each working cycle, the exhaust oil is merely released through external port AT' or port DT' to fall into the sump. In other applications, where the exhaust oil must be conducted back to tank T, valve ports AT' and DT' can be connected internally to a single port with a return line to tank T, as indicated by line L4 in FIG. V.

Valve spool 32 is maintained in mid-position by a special spring centering device SCD, comprising a single compression spring 37 working between a pair of "one-way" collars 38, 38' riding on valve stem VS and which normally rest against two stop-washers 39, 39', fixed in the bore of sleeve 31, as shown. The action of the spring centering device SCD is as follows: In the normal position shown, compression spring 37 presses the one-way collars 38, 38' against the fixed stop-washers 39, 39'; whereby valve spool 32 is resiliently held in mid-position. Assuming that valve stem VS is pulled outwardly, the inboard one-way collar 38' is carried against the resistance of compression spring 37, which latter therefore tends to return valve spool 32 back to mid-position. Assuming that valve stem VS is pushed inwardly, the outboard one-way collar 38 acts against compression spring 37, which tends to return valve spool 32 to mid-position, as before. Compression spring 37 is preferably made sufficiently strong that the operator of the pitch control handle can "feel" the give of the spring when that handle is moved from the rest position; and also sufficiently strong to restore the pitch control handle to true pitch-indicating position after release, as explained hereinafter.

Valve spool 32 is like a closed-center type with minimum over-lap for precision in oil control action, but it is special in that the mid-land may be slightly undersized, whereby there results a controlled leakage of pressure oil into port A' and port D'. The purpose of this leakage is to maintain equal oil pressures in these ports and their connections, notwithstanding any leakage therefrom; as for example around spool 32 at port AT' and port DT', or at the sealing rings in the pressure oil transfer unit. This permitted leakage feature gains several substantial advantages, namely, considerable pressure oil leakage is tolerable without affecting precision of operation; the working parts can be fit loose enough to maintain an anti-friction oil film; the usual hydraulic locking or rachet valve is eliminated; and the entire system is simplified and made more reliable and durable in operation. When this master valve is not of standard type, i.e. of neither open-center nor closed-center type, it is herein termed a "leaky-center" valve.

Duplicating Cylinder

The general purpose of the duplicating cylinder DC is to correlate hydraulically the movements of servo piston SP and master valve MV, thus giving the servo system a precise quantitative control characteristic. Duplicating cylinder DC comprises fixed piston 40 of double end-rod type, fitted to the second bore of hydramp body 30, which latter thus provides the traveling cylinder member of the hydramp valve combination. Since duplicating cylinder DC performs no mechanical work and operates at low pressure, it is advantageously constructed of light parts and materials. The stroke of duplicating cylinder DC is preferably designed to match the desired travel of the remote control linkage CL—usually three inches for small inboard engines and five inches for larger engines—while the bore is preferably designed to provide a volumetric displacement equal to that of servo piston SP; whereby the movements of hydramp valve HV are precisely correlated with both the movements of the pitch control handle PCH and servo piston SP. Piston 40 is fixed by suitable means on a light one-piece piston rod 41, preferably with threaded ends for purposes of convenient mounting in the transmission unit. Duplicating cylinder DC is preferably provided with quickly demountable cylinder heads 42, 42' retained in hydramp body 30 by retaining wires 43. Leakage of pressure oil between cylinder heads 42 and valve body 30, between these cylinder heads and piston rod 41, and between this rod and piston 40 is prevented by suitable commercial sealing rings 44, as indicated.

Piston 40 is provided with at least one longitudinal hole in which is tightly fitted a miniature double check-valve, herein termed calibrating valve CV, consisting of a thin shell 45 with orifice ends containing two balls 46 held tightly in their respective orifices by a common compression spring 47, as shown in FIG. IVA.

The balls of the opposed check-valve project slightly beyond the faces of piston 40, so as to be actuated by the cylinder heads 42, 42', whenever the hydramp valve approaches either end of its travel. Thus, as either cylinder head approaches piston 40 the closed check-valve at that end is pushed open, thus permitting air and pressure oil to flow through that piston. When pressure oil is first pumped into the system, merely manipulating the pitch controls to the extremes of travel causes the calibrating valves CV in hydramp valve HV and the synchro-valve SV in servo picton SP to pass any air tripped in the hydraulic system to the exhaust ports of the hydramp valve, so that the system is soon filled with "solid" oil. Furthermore, as trapped air is eliminated from the system, the movements of servo piston SP are brought into step with those of hydramp valve HV, i.e., synchronism of the servo system is automatically established. This self-synchronizing feature overcomes a nuisance drawback of certain hydraulic control systems of the prior art, wherein all the hydraulic lines and components must be carefully filled with "solid" oil, while carefully bleeding off any trapped air, before the hydraulic system could be put into operation and then synchronized by various calibrating methods. The automatic synchronizing feature thus contributes substantially to the practicality of the improved hydraulic control system of the invention.

Hydramp valve HV is usually mounted inside transmission unit TU by means of piston rod PR, so as to travel freely thereon for a distance equal to the working stroke of control linkage CL; but it can be located elsewhere when convenient, as for example at an oil pump or in an oil tank.

Pressure Oil Transfer Device

In all hydraulic controllable pitch propeller systems, special consideration must be given to the design of the rotary sealing device for transferring hydraulic fluid to and from the propeller shaft, in order to eliminate any leakage which might impair operation of the system. Naturally, the higher the fluid pressure and the velocity of the wearing surfaces, the greater the tendency to wear and leakage. Hence, in the case of high speed shafts, as here, the design should minimize wear of any oil sealing rings which bear against the shaft.

Referring now to FIG. III, which shows a preferred embodiment of the pressure oil transfer device POT according to the invention, the body element consists of a unitary sleeve 50, preferably located on drive shaft 21 near main thrust bearing 23, thereby to facilitate connections to coaxial conduit CC. Sleeve 50 has a smooth bore closely fitting drive shaft 21, but so that the shaft can rotate freely therein; this bore having four circumferential V-shaped sealing grooves and three intermediate distributing grooves, the outer of which are internally connected. The four V-shaped grooves are each adapted to retain a soft resilient sealing ring 51, preferably of commercial O-ring type. These rings have an internal diameter slightly less than the shaft, and an external diameter slightly larger than the diameter of the grooves, whereby the O-rings when assembled are placed under a certain radial compression or "squeeze," according to known practice. The purpose of the V-shape groove is to preserve the "squeeze," by wedging action of the oil pressure, despite minor wear. The purpose of the extra grooves and sealing ring is to normally equalize the pressures on opposite sides of the two middle O-rings, thereby to prevent wear and leakage at these sealing rings, which confine the oil in the hydraulic link. Minor leakage at the outside sealing rings has no effect on the operation of the hydraulic system.

In order further to minimize wear on the sealing rings in sleeve 50, it is preferable that sleeve 50 be mounted so

as to ride freely or float" on drive shaft 21, which facilitates lubrication and eases friction. Accordingly, sleeve 50 is provided with a crosswise retaining slot 54, which is loosely engaged by a demountable retaining bracket 55, fixed to housing 20 by suitable means such as one or more cap screws; thus preventing rotation of sleeve 50, while permitting same to "float" on drive shaft 21, as required.

Sleeve 50 is provided with two radial tapped ports C", D" leading respectively to the two inboard distributing grooves, these ports being adapted for assembly of the end fittings of the flexible lines L3, L2 leading to port B' and port D', respectively, of hydramp valve HV.

Drive shaft 21 is provided with two series of circumferentially arranged radial ducts leading from the inboard distributing grooves to the bore of that shaft. The inboard end of coaxial conduit CC is closed by cap 56 having a middle distributing groove and two packing grooves on either side, these packing groves each having an O-ring gasket. Coaxial conduit CC is also provided with small ducts in its walls opposite port C", all as shown.

From the foregoing description, it will be observed that pressure oil from line L3 passes via port C", one distributing groove and associated ducts into coaxial conduit CC, thence to chamber C in the propeller hub; while pressure oil from line L2 passes via port D", the other distributing groove and associated ducts into drive shaft 21; thence to chamber D in the propeller hub. This oil pressure lubricates all the working surfaces of the hydraulic apparatus, thus ensuring continuous pressure lubrication so long as pressure oil is supplied to the system. Since these surfaces are the main points of potential wear, it is evident that the special features provided to assure perfect lubrication contribute to the reliability and long life of the entire system.

Pitch Control System

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

Referring now to FIG. V, which shows schematically the entire system of the invention, the main elements are indicated diagrammatically, the details having been previously described. Certain parts of the apparatus indicated schematically, such as the remote control transmitter RCT, control linkages CL, pump P and relieve valve RV are of well-known commercial type, and hence need not be described in detail.

Suitable fluid conducting structures and connections, including lines, conduits, ports, passages, ducts, etc., generically termed hydraulic connections connect the various components of the hydraulic system in operative relation, as indicated in the schematic disgram. Pressure oil is supplied to connection C1 by pump P, excess oil being by-passed to sump or tank T by relief valve RV and connection C5. Line L1 of connection C1 leads to valve port P' of master valve MV (see FIG. IV), where further travel of the pressure oil is normally blocked by the mid-land of valve spool VS; except that there will be sufficient leakage into valve port A' and valve port D' to maintain full oil pressures therein; whereby the controlled parts of the hydraulic system are normally retained in set position.

Connection C2 extends from valve port D' of master valve MV via line L2 to port D" of pressure oil transfer POT, and thence via the hollows of the drive shaft DS and propeller shaft PS into chamber D of servo cylinder SC.

Connection C3 extends from the chamber B of duplicating cylinder DC via the annular passage B" in valve sleeve 31 to port B'; thence via working line L3 to port C" of pressure oil transfer POT; thence via coaxial conduit CC to the chamber C of servo cylinder SC of propeller assembly PA. It should be noted that connection C3 connects the two cylinders serially and thus constitutes the hydraulic linkage between hydramp valve HV and servo piston SP. Connection C4 extends from the exhaust ports AT' and DT' of hydramp valve HV to tank T.

The master pitch control element of remote control transmitter RCT, which may be of various commercial types, is the pitch control handle PCH, with which may be associated a visual pitch indicator PI and pitch indicating scale S, marked with symbols R, N, and F, meaning "reverse," "neutral" and "forward," respectively; however, the angular position of PCH indicates the pitch setting with sufficient accuracy for general maneuvring. Pitch control handle PCH is operatively connected to valve spool VS of master valve MV by means of light control linkage CL, which may be well-known push-pull Bowden-cable type such as that ordinarily used for engine throttle controls, or of two-way hydraulic remote control type. Remote control linkage CL is of course attached to valve stem VS, so as to transmit push-pull motion thereto. Multiple tandem remote control transmitters may also be used, in which case the remote controls should be of free type.

Synchronization

In order to cause servo piston SP to follow precisely the movements of pitch control handle PCH, the stroke of servo piston SP must be established and maintained in unison with the travel of hydramp valve HV; i.e. synchronism of their movements must be ensured. In practice, to establish synchronism all trapped and entrained air must be eliminated from the hydraulic system, and the start and finish of the stroke of servo piston SP and full travel of duplicating cylinder DC during any complete cycle must coincide. Actually, when all trapped air is eliminated, servo piston SP and duplicating cylinder DC must move together so long as the proper quantity of "linkage" oil is charged into the series hydraulic linkage connection C3, hence the main object of the synchronizing procedure is to bring this about.

Referring now to FIGS. IV and V, the following procedure may be used to put the hydraulic pitch control system into operation and to establish initial synchronism: Tank T having been filled with the specified charge of oil, pitch control handle PCH is set at the neutral N position, and the engine is started and run idly; whereupon pump P starts pumping pressure oil into connection C1, excess oil being by-passed by relief valve RV. Centrifugal force acting on the propeller blades will tend to bring these blades to "neutral" pitch when the engine is first started, if the servo piston SP is not under hydraulic control.

Pitch control handle PCH is then moved slowly towards the reverse R position; whereupon hydramp valve HV admits pressure oil to valve port D', thence to line L2, pressure oil transfer POT, and shaft bores to chamber D in hub H. Air pressure in chamber D moves servo piston SP outwardly (changing the pitch to "reverse") until it reaches the end of its stroke; whereupon synchro-valve SV opens, admitting air pressure to chamber C, thence via conduit CC, pressure oil transfer POT, line L3, port B' and connection B" to chamber D of duplicating cylinder DC. Air pressure in chamber D moves hydramp valve HV to the end of its travel, whereupon pressure air is by-passed by calibrating valve CV to chamber A, thence via connection A and valve port A' to port AT', where the trapped air in the system is vented to atmosphere. As the trapped air is released, it is followed by pressure oil, thus eventually filling the hydraulic system with almost "solid" oil. As pumping continues, pitch control handle PCH is moved slowly to the forward position, whereupon pressure oil is pumped thru the hydraulic system in the opposite direction; thus eliminating any trapped air not vented in the first place. When the trapped air is entirely replaced by "solid" oil (with servo piston SP and hydramp valve HV in their corresponding terminal

positions) the correct charge of "linkage" oil remains in the series linkage connection C3, whereby the stroke of servo piston SP is calibrated with the travel of hydramp valve HV. Thus, trapped air is automatically eliminated from the system and replaced by "solid" oil in the correct amount to calibrate the movements of servo piston SP and hydramp valve HV; thus automatically establishing synchronism of the system, merely by manipulation of control handle PCH thru its operating range, This unique feature overcomes the drawbacks of certain hydraulic pitch control systems of the prior art in which filling the system with oil, eliminating entrapped air, and then calibrating the system requires a tedious step-by-step manual procedure.

Moreover, with this system, synchronism is automatically checked and restored whenever pitch control handle PCH is set at the forward F or reverse R limits.

Operation of Pitch Control System

Assuming that all the operating parts of the pitch control system are at rest in mid or neutral position, the normal operation of the system is as follows:

The pitch control handle PCH being in neutral position, indicated by symbol N on the pitch indicator scale, and the blades B being in neutral pitch, i.e. the pitch at which the propeller produces no effective thrust, the driving engine can be started and the engine throttle set at idling speed without putting way on the boat. It should be noted, however, that in neutral pitch blades B stir and circulate the water in which they are submerged, hence they absorb power; which power increases rapidly with increase of engine speed. Hence, there is no danger of the engine running wild when the propeller is in neutral pitch; whereas with the conventional clutch transmission, when the clutch is in neutral power absorption vanishes; hence should the engine throttle be open when the clutch is shifted to neutral, the engine can race widly and dangerously. Thus, the novel system of the invention eliminates a common danger in handling motorboat engines.

Upon moving pitch control handle PCH towards forward F position, control linkage CL pulls valve spool VS somewhat outwardly; thereby exhaust oil is released at port DT' while pressure oil enters port A' in substantially the same amount. Pressure oil extends from port A' via connection A'' to chamber A of duplicating cylinder DC, and as pressure oil enters this chamber—since duplicating piston DP is fixed—the entire hydramp valve HV is forced to travel along piston rod PR in the direction and degree of the prior displacement of valve spool VS. The effect of this "follow-up" movement is to close master valve MV at the temporary position of pitch control handle PCH, which must be moved with hydramp valve HV to continue the pitch changing action. In other words, duplicating cylinder DC functions so as to cause hydramp valve HV to follow the directional movements of pitch control handle PCH, and also to precisely counteract these movements. Moreover, the rate or speed of hydramp valve HV is correlated with that of pitch control handle PCH, within certain limits set by the spring centering device SCD, hence this valve functions as a true directional and proportional hydraulic amplifier.

Dynamically viewed, working response of the hydraulic system to movement of the spool of master valve MV depends upon the differential pressure in valve ports A' and D' at the ends of the working circuit. Normally, the pressures in these ports are equalized by leakage from pressure oil port P', hence the hydraulic forces in the system are maintained in balance. But when one or the other of these ports is connected to exhaust, oil pressure drops at that end of the system; hence a pressure differential is produced around the working circuit, enabling servo piston SP to do the work necessary to change the pitch. While movement of pitch control handle PCH produces a momentary pressure differential, follow-up movement of hydramp valve HV restores the pressure balance. It follows that quick movement of pitch control handle PCH produces a quick working response, and vice versa; hence the rate of pitch change can be varied within limits by the operator. This feature thus contributes to ease and precision in operation of the pitch control system.

Entrance of pressure oil into one chamber of duplicating cylinder DC expels an equal quantity of oil from the other chamber, hence due to series connection C3 this equal quantity of displaced oil, termed "linkage oil," enters the outboard chamber C of servo cylinder SC; thus forcing a corresponding displacement of oil from the other chamber D; and thence via connection C2 to valve port D', where it is released for return to tank T. The travel of servo piston SP and change of pitch of blades B will accordingly be controlled by pitch control handle PCH in direct proportion to the quantity of displaced oil, and hence to the movement of hydramp valve HV.

When the operator releases pitch control handle PCH, the compression spring 37 of spring centering device SCD takes up any lost motion due to overlap in hydramp valve HV or in the remote controls, thereby restoring a precise relation between the position of hydramp valve H and that of pitch control handle PCH, which thus precisely indicates, when released, the exact pitch of the propeller.

To reduce or reverse the pitch, pitch control handle PCH is merely moved in the direction towards the reverse R limit; whereupon a reverse sequence of pitch changing operations occurs, beginning with release of exhaust oil from port A', and entry of pressure oil into port D'; whereby the pitch of blades B is changed in the reverse direction according to the quantity of displaced oil, as indicated by the rest position of pitch control handle PCH.

It may be observed from the foregoing that in the normal operation of the pitch control system full oil pressure is maintained at the working ends of the hydraulic circuit because of controlled leakage of pressure oil from the oil supply port P' into valve port A' and valve port D'. Thereby the effects of thermal expansion of the oil or of any leakage, except from the hydraulic link connection C3, are eliminated. Slow leakage of oil from the hydraulic linkage connection C3 might occur by reason of wear of the middle sealing rings in the pressure oil transfer POT, but such tendency is effectively countered by equalizing the oil pressure on both sides of these rings. Wear of all the sealing rings in pressure oil transfer POT is also minimized by the "floating sleeve" feature. Moreover, should any leakage occur in the linkage connection system, such error will become evident during operation by drifting of pitch control handle PCH into the "overpitch" range.

It follows from the foregoing that the actual accuracy of pitch indication can be checked upon getting underway merely by setting pitch control handle PCH at neutral N position, because if there is no tendency for the propeller to move the boat ahead or aback, the entire pitch control system is properly calibrated. If intolerable error is found, accuracy of calibration can be restored merely by manipulating pitch control handle PCH thru an operating cycle, as priorly explained. This feature overcomes a dangerous drawback of certain hydraulic pitch control systems of the prior art using "locked" controls; which are incapable of indicating or correcting the actual pitch, and have been known to give a wrong response during maneuvering. Obviously, such malfunction is impossible with the system described.

A further safeguard against malfunction is provided by the "sensory" characteristics of the pitch control system. For example when the pitch control handle PCH is moved from rest position, the "give" of the compression spring in the spring centering device SCD can be felt by the operator; followed by yeilding due to follow-up movement of hydramp valve HV. Any failure to respond properly would thus become evident to the operator at once by sense of touch.

The pitch control system described is also well adapted for tandem operation from more than one control station, since each pitch control handle PCH is "free" and also indicates the actual pitch. Hence, without preliminary operations, the propeller pitch can be controlled interchangeably from any control station—a feature of particular interest to sport fishermen.

From the foregoing, it seems evident that the concept of the hydraulic control system of the invention improves on the ordinary concept of hydraulic controls in that minor oil leakage in the system is not only rendered harmless, but is utilized beneficially to keep the servo piston under proper constraint (in lieu of locking the controls and/or controlled apparatus); to compensate for thermal expansion of the hydraulic fluid; to provide pressure lubrication of all working surfaces; and to provide a warning indication of any accumulated inaccurcy. Furthermore, the automatic scavenging feature in combination with the self-synchronizing feature gains numerous unique advantages in practice; including ease and time savings in installation, and safe, reliable operation by unskilled operators.

It should be noted that the pitch control system of the invention constitutes an automatic hydraulic position-control servo-system of closed-cycle type; in which the pitch control handle constitutes the input control member; the pump the power source; the servo-piston the controlled output or load member; the hydraulic amplifier valve constitutes a combination of the controller, the follow-up device, the error detecting device, the error correcting device, and the power amplifier device; and the cam-crank pin movement provides the power applying and stabilizing device. In this connection, it may be noted that if the pitch control handle were locked in the set position, should the servo-piston be forced out of the controlled position, the reaction of the hydraulic amplifier valve would automatically apply error correcting power to restore the servo-piston to the controlled position. However, locking the pitch control member sacrifices the "answer-back" and pitch indicating features, hence it is usually preferable to operate the system with the pitch control handle free to move in accordance with the actual pitch.

While a particular mechanical arrangement has been illustrated in the accompanying drawings and hereinabove described for the purpose of disclosing the invention, it is to be understood that the invention is not limited to the particular construction so illustrated and described, but that such changes in the size, shape and arrangements of the various parts may be resorted to as come within the scope of the subjoined claims.

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

1. A hydraulic controllable pitch marine propeller system comprising, in combination: a tubular propeller shaft; a hollow hub, having a central axial bore, fixed tightly to said shaft and mounting journaled blades capable of pitch changing axial rotation; mechanism within said hub for turning said blades axially in unison including a double-acting hydraulic motor-cylinder having two chambers for liquid and a rodless servo-piston displaceable in opposite axial directions in said bore by differential pressure of liquid in said chambers; a power source of pressure liquid; a traveling hydraulic amplifier valve for controlling quantitatively the flow of pressure and exhaust liquids, said valve having five liquid conducting valve ports the middle one of which is hydraulically connected to said source of pressure liquid, an axially slidable valve spool for varying the liquid pressure in said valve ports, a spring centering device for said valve spool, and an integral double-acting traveling duplicating cylinder with two chambers separated by a stationary piston; a hydraulic connection between one of said valve ports and one chamber of said duplicating cylinder; a second hydraulic connection between another of said valve ports and one chamber of said motor-cylinder; a third hydraulic linkage connection between the other chamber of said motor-cylinder and the other chamber of said duplicating cylinder; whereby coordinated differential liquid pressures and flows are produced in said chambers under control of said hydraulic amplifier valve; and means for synchronizing the movements of said servo piston and said traveling hydraulic amplifier valve, said means including a synchro-valve within said motor-cylinder actuated by said servo-piston and a calibrating valve carried by said stationary piston and actuated by said traveling duplicating cylinder; whereby the movements of said servo piston are established and maintained in unison with those of said hydraulic amplifier valve.

2. A hydraulic controllable pitch marine propeller system comprising in combination: a tubular propeller shaft; a hollow hub, having a central axial bore, fixed tightly to said shaft and mounting journaled blades capable of pitch changing axial rotation; mechanism within said hub for turning said blades axially in unison, including a double-acting hydraulic motor-cylinder having two chambers for liquid and a rodless servo-piston displaceable in opposite axial directions in said bore by differential pressure of liquid in said chambers; a power source of pressure liquid; a traveling automatic hydraulic amplifier valve, including a double-acting traveling duplicating-cylinder, for controlling quantitatively the flow of pressure and exhaust liquid; proper hydraulic connections between said source, said valve, said duplicating-cylinder and said motor-cylinder, whereby said valve controls the differential pressure of liquid acting on said duplicating cylinder and consequent travel of said duplicating-cylinder controls the displacement of said servo-piston; and automatic valve means for synchronizing the displacement of said servo-piston in accordance with the travel of said duplicating cylinder.

3. A hydraulic controllable pitch marine propeller system comprising in combination: a tubular propeller shaft; a hollow hub, having an axial cylindrical bore, fixed tightly to said shaft and mounting radial journaled blades; mechanism with said hub for turning said blades axially in unison, including a double-acting servo-piston displaceable in said bore according to the quantity of pressure liquid therein; a power source of pressure liquid; a traveling automatic hydraulic amplifier valve, having an integral traveling double-acting duplicating-cylinder hydraulically controlled by said valve, for controlling quantitatively the flow of pressure liquid in precise proportion to the travel of said valve; and proper hydraulic connections between said source, said valve, said duplicating-cylinder and said hub bore, whereby said valve controls the quantity of pressure liquid displacing said servo-piston; and automatic valve means for synchronizing the displacement of said servo-piston in accordance with the travel of said valve.

4. A hydraulic controllable pitch marine propeller system comprising in combination: a tubular propeller shaft; a hollow hub, having a cylindrical axial bore, fixed tightly to said shaft and mounting journaled radial blades; mechanism within said hub for turning said blades axially in unison, including a double-acting servo-piston displaceable axially in said bore according to the quantity of pressure liquid therein; a power source of pressure liquid; a traveling automatic hydraulic amplifier valve, having an axially displaceable spring-centered valve spool and an integral double-acting traveling duplicating-cylinder hydraulically controlled by said valve, for controlling quantitatively the flow of pressure and exhaust liquid in said system; and proper hydraulic connections between said source, said valve, said duplicating-cylinder and said bore, whereby said hydraulic amplifier valve controls the quantity of pressure liquid displacing said servo-piston according to the displacement of said valve spool; and automatic including a calibrating valve actuated by said

duplicating-cylinder and a synchro-valve actuated by said servo-piston for synchronizing the displacement of said servo-piston in accordance with the displacement of said valve spool.

5. In a controllable pitch propeller system including blades turnable about their axes, the combination comprising: a double-acting servo-piston displaceable by pressure liquid for turning said blades; means for supplying pressure liquid to said system; an automatic traveling hydraulic amplifier valve, including an axially displaceable spring-centered valve spool and an integral double-acting traveling duplicating-cylinder hydraulically conrtollable by said valve, for controlling quantitatively the flow of pressure liquid; and proper hydraulic connection between said source, said valve, said duplicating-cylinder and said servo-piston; whereby the displacement of said valve spool controls the quantity of pressure fluid supplied to the servo-piston or to the duplicating-cylinder; and automatic means including a calibrating valve actuated by travel of said duplicating-cylinder and a synchro-valve actuated by displacement of said servo-piston for synchronizing the displacement of said srevo-piston according to the displacement of said valve spool.

6. In a hydraulically powered position-control servo-system, the combination of: a double-acting hydraulic servo-motor having a bore with two chambers for liquid and a servo-piston displaceable in opposite directions in said bore by unbalanced pressure of liquid in said chambers; a power source of pressure liquid; a traveling automatic hydraulic amplifier valve for measuring liquid passing therethru including a traveling double-acting duplicating-cylinder having a bore with two chambers and a fixed piston, and an integral master valve having a pressure liquid inlet port, two liquid distribution ports, two liquid exhaust ports and an axially movable spring-centered valve spool for controlling the flow of liquid thru said ports; proper hydraulic connections between said source, said valve, said duplicating-cylinder and said servo-motor; so that these are connected serially in a hydraulic circuit; whereby reversible movement of said valve spool controls the flow of pressure liquid alternatively to said duplicating-cylinder or to said servo-motor, thereby operating them reversibly, and travel of said duplicating cylinder measures the quantity of liquid flowing thru said ports; and automatic means for synchronizing the displacement of said servo-piston in accordance with the travel of said valve spool, whereby the position of said valve spool automatically controls the position of said servo-piston.

7. The combination specified in claim 6, in which the fixed piston carries valve means capable of opening a passage therethru whenever said duplicating-cylinder approaches the ends of its travel and said servo piston has valve means capable of opening a passage therethru whenever it approaches the ends of its stroke.

8. In a hydraulically powered position-control servo-system, the combination of: a double-acting hydraulic servo motor having a bore with two chambers for liquid and a servo-piston displaceable in opposite directions in said bore by differential pressure of liquid in said chambers; a power source of pressure liquid; a traveling automatic hydraulic amplifier valve for measuring the quantity of liquid applied to said srevo-motor, including a traveling double-acting duplicating-cylinder having a bore with two chambers separated by a fixed piston, and an integral master valve having a pressure liquid inlet port, two liquid distribution ports, two liquid discharge ports and an axially movable spring-centered valve spool for controlling the differential liquid pressure in said distribution ports and flow of liquid thru all said ports; proper hydraulic connections between said source, said valve, said duplicating-cylinder and said servo-motor, so that these are connected serially in a hydraulic circuit; whereby movement of said traveling valve spool controls the flow of pressure liquid alternatively to said duplicating-cylinder or to said servo motor, thereby operating them reversibly, and travel of said duplicating-cylinder limits the quantity of liquid flowing thru said ports; and automatic valve means for synchronizing the displacement of said servo-piston in accordance with the travel of said valve spool; whereby the position of said valve spool automatically controls the position of said servo-piston.

9. The combination specified in claim 8, wherein manipulation of said valve spool exhausts trapped air from said system and establishes synchronism of the movements of the servo-piston and duplicating-cylinder.

10. The hydraulic amplifier valve of claim 9, in which the middle land portion is slightly undersized to permit of some leakage of pressure fluid into said distribution ports, thereby normally to equalize the fluid pressures therein.

11. In a hydraulic remote control system, a traveling automatic hydraulic amplifier valve of quantitative liquid control type including: a body member having two parallel axial cylindrical bores, one of said bores being closed and forming a double-chambered duplicating cylinder integral with said body member; a double end-rod piston in said cylinder adapted to be fixed in position so as to guide travel of said cylinder; a sleeve member tightly fit in the other parallel bore, said sleeve member having an axial cylindrical bore and having a middle liquid inlet port adapted for connection to a power supply source of pressure liquid, two working liquid disrtibution ports adjacent said inlet port, and two liquid discharge ports respectively adjacent said distribution ports; a valve spool axially slidable in said bore of said sleeve, said spool having a middle land portion normally blocking said inlet port, and two end portions normally blocking said liquid discharge ports; a single compression-spring device, for resiliently centering said valve spool, assembled in said bore of said sleeve and operatively connected to said valve spool; a liquid passage between one of said distribution ports and one chamber of said duplicating cylinder; and automatic calibrating valve means carried by said piston and actuated by said duplicating cylinder at each end of its travel.

12. In a hydraulic remote control system, an automatic traveling hydraulic amplifier valve of quantitative liquid control type including: a body member having two parallel axial cylindrical bores, one of said bores being closed and forming a double-chambered duplicating cylinder integral with said body member; a double end-rod piston mounted in said cylinder so as to produce travel of said cylinder, a sleeve member tightly fitted in the other parallel bore, said sleeve member having an axial cylindrical bore and having a middle liquid inlet port adapted for connection to a powered source of pressure liquid, two working liquid distribution ports adjacent said inlet port and two liquid discharge ports respectively adjacent said distribution ports; a valve spool axially slidable in said bore of said sleeve, said spool having a middle land for normally blocking flow of liquid from said inlet port, and two end portions for normally closing said liquid discharge ports; a single compression-spring device for resiliently centering said valve spool assembled in said bore of said sleeve and operatively connected to said valve spool; a liquid passage between one of said distribution ports and one chamber of said duplicating cylinder; a port connected with the other chamber of said duplicating cylinder; and calibrating valve means carried by said piston and actuated by said duplicating cylinder at each end of the stroke to open a passage through said piston.

13. A valve according to claim 12 in which the middle land of the valve spool is undersize for normally equalizing the liquid pressures in said distribution ports.

14. A transmission unit for use with a hydraulic controllable pitch propeller comprising in combination: a hollow casing; a hollow drive shaft mounted rotatably in said casing; a stationary pressure liquid pump mounted

around and driven by said drive shaft; a relief valve for limiting the liquid pressure; a traveling automatic hydraulic amplifier valve mounted so as to reciprocate therein in said casing; a pressure liquid transfer device, mounted around said drive shaft, for conducting liquid into and out of said drive shaft; and proper hydraulic connections between said pump, said relief valve, and said pressure liquid transfer device.

15. A hydraulic controllable pitch marine propeller system comprising in combination: a tubular propeller shaft; a hollow hub, having an axial cylindrical bore, fixed tightly to said shaft and mounting radial journaled blades; mechanism within said hub for turning said blades axially in unison, including a double-acting servo-piston displaceable in said bore by applied differential liquid pressure; a power source of pressure liquid; an automatic traveling hydraulic amplifier valve, having a slidable valve spool and an integral double-acting traveling duplicating-cylinder, for controlling the pressure, quantity and direction of applied liquid; proper hydraulic connections between said source, said valve, said servo-piston and said duplicating-cylinder, whereby said valve controls the differential pressure and travel of said duplicating cylinder controls the quantity of liquid applied to said servo-piston; automatic means for synchronizing the movement of said servo-piston with said valve; and remote control means including a pitch control member operatively connected to said valve spool; whereby the position of said pitch control member controls and indicates the effective pitch of said propeller.

16. In a hydraulic remote control system, the combination of: a remote working servo-motor having a double-acting cylinder and a servo-piston relatively displaceable in said cylinder according to the quantity of pressure liquid applied to said servo-motor from a power source of pressure liquid; a master control unit for hydraulically controlling said servo-motor including a traveling master hydraulic amplifier valve for measuring automatically the quantity of pressure liquid applied to said servo-motor and including a fixed piston and a traveling double-acting hydraulic duplicating-cylinder translatable relative to said fixed piston in proportion to the quantity of pressure liquid applied to said servo-motor; automatic synchronizing valve means in said servo-motor and in said duplicating-cylinder for synchronizing their movements; and proper hydraulic connections between said source, said valve, said duplicating-cylinder and said servo-motor; whereby operation of said valve automatically synchronizes and controls the movements of said servo-motor.

17. In a pressure-liquid control valve of automatic liquid measuring type, the combination comprising: a body member having a cylindrical open bore and a parallel closed cylindrical bore constituting a double-acting duplicating cylinder; a piston with double end rods separating said closed bore into two variable chambers; a sleeve member with an axial bore fitted tightly in said open bore and having a middle pressure-liquid inlet port, two working liquid distribution ports adjacent said inlet port, and two liquid discharge ports respectively adjacent said distribution ports; a passage connecting one of said liquid distribution ports with one chamber of said duplicating-cylinder; a port connected with the other chamber of said duplicating-cylinder; a valve spool having a valve stem slidable axially in said axial bore, said valve spool having a middle cylindrical land normally blocking flow of pressure-liquid thru said inlet port and cylindrical lands beyond said distribution ports for selectively controlling discharge of liquid thru said discharge ports; and a resilient spool centering device assembled in said axial bore and having a single coiled compression spring mounted on said valve stem for normally holding said valve spool in mid position.

18. The combination specified in claim 17 in which the middle cylindrical land of said valve spool is slightly under-sized so as to permit some continuous leakage of pressure liquid into said distribution ports, thereby normally to maintain equal equal liquid pressures therein.

19. In an automatic liquid measuring valve, the combination comprising: a body member having a longitudinal open bore and a parallel closed bore constituting a double-acting cylinder; a piston tightly reciprocable within and separating said closed bore into two variable liquid measuring chambers; a sleeve member with an axial bore fitted tightly in said open bore and having a series of transverse liquid flow control ports; a passage connecting one of said ports with one chamber of said cylinder; a valve spool having a stem assembled axially slidable in said axial bore, said valve spool having cylindrical lands blocking certain of said ports when in mid position; a resilient spool centering device assembled around said valve stem and having a single coiled compression spring mounted for normally holding said valve spool in mid position; and automatic valve means for opening a normally closed passage between said variable chambers at both ends of the travel of said piston.

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