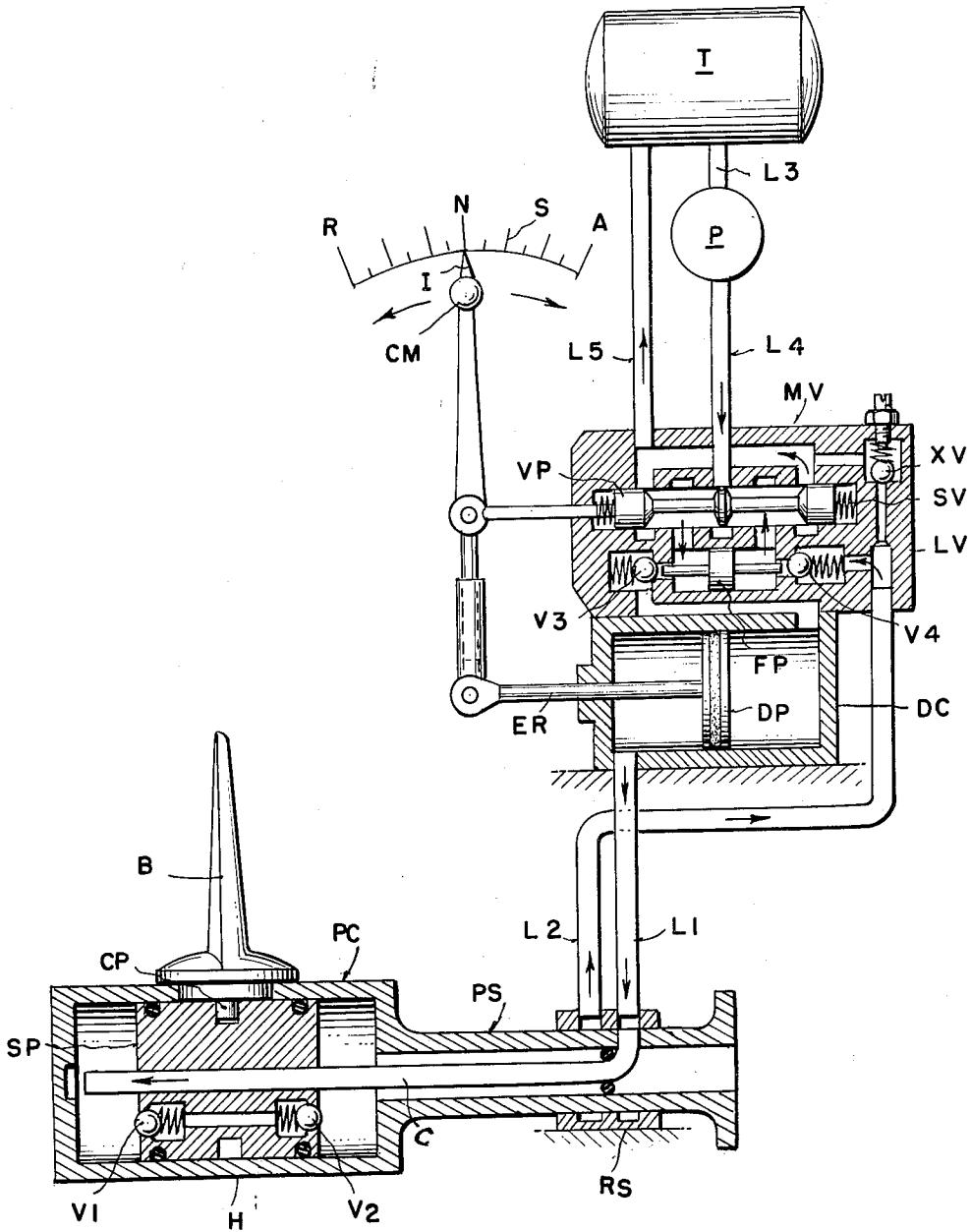


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HYDRAULIC PITCH CONTROL SYSTEM

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HYDRAULIC PITCH CONTROL SYSTEM

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This invention relates to improvements in hydraulic remote controls and has particular reference to an improved hydraulic pitch control system for controllable pitch propellers.

An object resides in the provision of an improved hydraulic control system characterized by reliability, accuracy, utmost simplicity, compactness, a minimum of component parts, and maximum economy in first cost and operation, thereby to facilitate mass production and standardization.

A further object resides in the provision of semi-automatic means for coordinating the movements of the hydraulic servo piston which actuates the pitch changing mechanism with the movements of a master pitch control member.

A still further object resides in the provision of a pitch control system in which the rest position of the master pitch control member automatically indicates the pitch of the propeller blades.

Yet another object resides in the provision of a hydraulic device which automatically locks the blades in any pitch to which they may be set.

Other objects and advantages will be more particularly pointed out hereinafter or will become apparent as the description proceeds.

In the accompanying drawings, in which like reference symbols are utilized to designate similar parts throughout, there is illustrated a suitable mechanical and hydraulic arrangement for the purpose of disclosing the invention. It is to be understood, however, that the drawings are for the purpose of illustration only and are not to be taken as limiting or restricting the invention since it will be apparent to those skilled in the art that various changes in the illustrated arrangement may be resorted to without in any way exceeding the scope of the invention.

The single drawing is a schematic diagram of one embodiment of the invention which illustrates typical component apparatus, hydraulic circuits and the principle of operation of the system of the invention.

Referring to the drawing, the propeller, which is shown schematically, includes a hollow hub generally indicated at H carried by a tubular propeller shaft PS and in which are rotatably mounted a plurality of blades B; and pitch changing mechanism mounted therein including a hydraulic servo motor comprising propeller cylinder PC and a servo piston, indicated generally by SP, and crank pins CP, carried by the blades. A pitch changing mechanism suitable for carrying out the present invention is particularly illustrated and described in my co-pending application for U. S. Letters Patent Ser. No. 62,017 filed November 26, 1948, to which reference is made for further details. For present purposes it should be noted that servo piston SP, whose position is hydraulically controlled, upon axial translation in the bore of the hub imparts an equal turning moment to each of the blades by means of the crank pins.

The servo piston SP is also provided with one or more calibrating valves V1, V2, here shown as opposed spring-

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loaded ball check valves or other suitable forms altho spring-loaded pin check valves may be employed instead; which valves are connected by a longitudinal passage in the piston, as shown. Each valve is assembled in the end of the piston so that the movable member of the valve, say the ball, projects slightly beyond the face of the piston, so as to be actuated by the end walls of the chamber when the piston is moved to either of its extreme positions. Thus, as the piston approaches one or the other end wall, the closed check valve at that end is pushed open, permitting fluid to by-pass from the pressure to the exhaust end of the piston, thereby limiting the stroke of the piston. When fluid under pressure is first introduced into the hydraulic system, the check valves by-pass any trapped air around the piston, permitting such air to be eliminated from the hydraulic system. This same by-passing action coordinates the stroke of the servo piston with that of the duplicating piston, as described hereinafter. These opposed check valves thus combine the functions of a pitch-limit device, auxiliary means for bleeding air from the hydraulic system, and an automatic calibrating device, but for brevity they are hereinafter referred to as synchronizing valves.

Hydraulic fluid under pressure may be supplied to the propeller cylinder PC through coaxial conduit C and through the passage between that conduit and the propeller shaft. Fluid may be supplied from external hydraulic line L1 into conduit C, and from external line L2 into the said passage by suitable rotary sealing means, indicated generally at RS, as for example that described in detail in the aforesaid co-pending application.

The source of pressure fluid may comprise a pump, generally indicated at P, supplied from a fluid reservoir or tank, generally indicated at T. Pump P may be connected to the tank T by suction line L3 and to master valve MV, described hereinafter, by pressure line L4, while master valve is connected to tank T by exhaust line L5.

A hydraulic motor, comprising a hydraulic duplicator cylinder DC and a duplicating piston DP provided with an end rod ER, is hydraulically connected in series between master valve MV and one chamber of propeller cylinder PC. The displacement capacity of the serially connected chambers should be substantially equal. Thus upon coordination of the relative positions of servo piston SP and duplicating piston DP, by action of the calibrating valves as above described, said pistons will perform duplicate movements; that is the movements of piston DP and piston SP will be synchronized.

In order to simplify the hydraulic lines, duplicator cylinder DC preferably carries the master valve MV, as indicated, comprising servo-valve SV, which is preferably of 3-position, 4-connection, open center type, and is preferably provided with a spring-centered valve-spool or plunger VP; a pressure actuated locking valve LV, sometimes known as a "ratchet-valve," comprising a floating actuating piston FP and opposed spring loaded check valves V3, V4, and a safety and thermal expansion relief valve XV of adjustable type hydraulically connected to the servo-valve SV, and which may be made integral therewith, as indicated, to simplify the hydraulic connections. Servo-valve SV is provided with a center intake port connected to pressure line L4, working or distribution ports directly connected to lock valve LV, and end exhaust ports connected to exhaust line L5, all as indicated. Lock valve LV is provided with ports connected by passages to the working ports of servo-valve SV, a port connected to the blind end of duplicator cylinder DC, and a port connected to working line L2. The rod end of duplicator cylinder DC is connected to working line L1.

A master control member CM in the form of a floating differential lever is pivotally supported by the stem of

valve plunger VP and is operatively connected to the rod of duplicating piston DP by a sleeve or telescope joint, as indicated, or by other suitable means.

The master control member CM is preferably operatively associated with an indicator pointer I and a calibrated position scale S, or equivalents, for purposes of visually indicating the pitch, as explained hereinafter. The servo-valve SV can be actuated by control forces of a weak order, and the control member CM being normally free, the control system of the invention is well-adapted for remote control from one or more stations. For example, in case the master control member CM were located in the engine room, conventional remote controls could be installed whereby the master control member could be actuated from the wheel house. For operation by remote control, any remote control member would of course be provided with pitch indicating means, similar to that illustrated.

Operation

The operation of the pitch control system whose components were described above is as follows: All the working parts are assumed to be in mid position and the blades in neutral pitch, as indicated by their position and the pitch indicator being at neutral position N on the scale S. When the system is in non-operating condition, valve plunger VP is in neutral position, thus servo-valve SV is open and fluid passes freely from pressure line L4 via the servo-valve ports to exhaust line L5. The pump P therefore normally runs unloaded and absorbs the minimum of driving power. This is an important practical feature of the system which saves power when idling, which it does nearly all the time, and greatly prolongs the life of the pump and pump driving means.

If the control member CM be then displaced clockwise towards the "Ahead" position, indicated at A on the scale, the servo-valve plunger VP will be displaced to the right, thereby closing the left exhaust port, and fluid will then flow in the hydraulic circuits as indicated by the small arrows. Pressure fluid pushes floating piston FP of lock valve LV to the right, thus opening check valve V4 and permitting fluid to be exhausted from the right end of propeller cylinder PC through line L2, valve V4 and thence via the right ports of servo-valve SV to exhaust line L5. Concurrently, the fluid pressure unseats check valve V3 admitting pressure fluid to the head end of duplicator cylinder DC, forcing duplicating piston DP to move to the left, thereby displacing fluid under pressure from the rod end of the cylinder via line L1 and conduit C into the outboard (left) end of the propeller cylinder PC. This fluid pushes servo piston SP to the right, turning the blades so as to cause an increase of pitch. Since the movements of the control member CM and servo piston SP are coordinated, the operator cannot move that member faster than the rate at which the pump P can move servo piston SP.

Due however to the follow-up movement imparted to the valve plunger VP by movement of the lower end of control member CM due to the movement of the duplicating piston DP, the servo-valve ports tend to re-open as the pitch is changed, and unless the movement of the control member CM is continued, the pitch changing cycle will be terminated by such follow-up movement, due to return of the servo-valve to open center condition. When this occurs, the pressure on floating piston FP is relieved and both the check valves V3 and V4 promptly close, thus locking the hydraulic fluid in the circuits leading to the propeller cylinder PC. Thus, the blades are locked hydraulically in any set position.

It should also be observed that the valve plunger VP when initially displaced from neutral position produced some compression of the right valve-spool centering spring. Upon release of control member CM, any lost motion which may have occurred will be restored by the centering springs, thus producing an accurate pitch indication, provided, of course, the control member is permitted to

move freely upon release, as it should in practice. However, if the control member cannot move freely, the only consequence would be a slight error in pitch indication, and the pump would operate under some degree of partial load, rather than no load, due to partial opening of the servo-valve.

To decrease or reverse the pitch, the control member CM is simply moved counterclockwise towards the "Reverse" position indicated by R on the scale, whereupon valve plunger VP will be displaced to the left and a pitch changing cycle of the same order but opposite in direction will be performed.

Detailed analysis will show that the movement of the servo piston SP will be exactly proportional to the movement of the duplicating piston DP, provided there is no leakage in the closed portion of the hydraulic circuit connecting these components. This follows from the fact that fluid is displaced directly from the motor cylinder into the propeller cylinder, and vice versa. Further, the lock valve LV positively locks the fluid in the closed portion of the system so as to prevent any change of the set pitch. Leakage in the servo-valve will not affect the pitch setting. Hence, if adequate hydraulic packings are provided and the system is properly calibrated, correspondence will be maintained indefinitely between the movements of the control member and the blades. These features contribute importantly to the characteristic accuracy and reliability of the system.

However, should any minor leakage occur in the locked portion of the hydraulic circuit which might cause a loss of calibration, the system can be immediately recalibrated as follows: The control member CM is moved to one extreme position, then to the other, to reverse the pitch completely. Should the servo piston SP reach the end of its stroke before the duplicating piston DP reaches the end of its stroke, sufficient fluid will be by-passed around the servo piston by calibrating valves V1, V2, to enable piston DP to complete its stroke; and upon reversing the stroke, the system will be re-calibrated. Vice versa, the system will be synchronized at the other end of the stroke. Thus, the calibrating valve means regulates the quantity of liquid operationally interconnecting pistons SP and DP, so as to ensure duplication in their movements. Such check of the calibration would of course be part of the regular routine check of the pitch control system, but in any event could be performed any time the system is in operation, and would be performed automatically whenever the pitch is completely reversed.

It seems evident without further discussion that the semi-automatic calibrating feature provided by the present invention is of primary practical importance, and overcomes a major defect of some systems of the prior art in which any loss of calibration involved extensive and inconvenient remedial measures.

It should be noted that the pitch control system of the invention constitutes a servo-system of position-control type in which the control member constitutes the input member; the servo piston the controlled member; the blades; the load; the duplicator cylinder, differential lever and servo-valve the differential error detecting device; the pump and servo-valve the power source and amplifier; and the lock valve the stabilizing device.

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 sub-joined 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. In a hydraulically actuated controllable pitch propeller system including a tubular shaft carrying a hub

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having blades mounted thereon for pitch changing movements; the combination comprising mechanism in said hub for changing the pitch of said blades including a servo motor having a servo piston connected positively to said blades and valve means for calibrating the position of said piston and actuated at either end of the stroke of said piston to pass fluid therethrough; a power source of fluid; a servo valve connected hydraulically to said source and having valve ports and a movable valve member for controlling the passage of fluid through said ports; two hydraulic lines extending from said servo motor through said shaft to two fluid distribution ports of said servo valve; a hydraulic follow-up motor comprising a double-acting duplicating piston and a cylinder hydraulically connected in one of said lines serially with said servo motor; automatic valve means connected hydraulically in both said lines for normally locking fluid in both said motors; a control member constituting a differential lever operatively connected to said valve member so as to impart direct movement thereto and to said duplicating piston so as to receive followup movement therefrom; and means for indicating the pitch associated with said control member; whereby the said servo piston is caused to follow precisely the movements of said control member to change the pitch of said blades in controlled direction and degree and to lock the blades in any set pitch. and whereby the rest position of said control member automatically indicates the set pitch of the blades.

2. In a hydraulic power servo system for controlling and indicating the pitch of the blades of a controllable pitch propeller, in combination; a fluid operated servo piston positively connected to said blades; calibrating valve means within said servo piston and actuated at either end of its stroke to permit passage of fluid therethrough; a power source of circulating pressure fluid having a pressure fluid outlet and return fluid inlet; a servo valve having valve ports connected to said outlet and inlet and two distribution valve ports either of which may conduct pressure fluid or exhaust fluid and a movable valve member for controlling the passage of fluid through said ports; two hydraulic lines terminating at the opposite ends of said servo piston and at the said distribution valve ports; a hydraulic cylinder having a double-acting duplicating piston translatable therein connected serially in one of said hydraulic lines; a pitch control member constituting a differential lever connected to said movable valve member and to said duplicating piston so that said valve member receives direct operating movement from said pitch control member and follow-up movement from said duplicating piston; whereby the position of said pitch control member continuously controls and indicates the pitch of said blades.

3. In a hydraulically actuated controllable pitch propeller system having blades mounted for pitch changing movements, mechanism for controlling the pitch of said blades comprising a hydraulic cylinder having a double-acting servo piston; mechanical connections for connecting said servo piston to said blades for positive movement thereof; a fluid control valve having a port for admitting pressure fluid, another port for discharging return fluid, two distribution ports either of which may conduct pressure or return fluid and a movable valve plunger for controlling the passage of fluid through said ports; two hydraulic lines terminating at the opposite ends of said servo piston and at said distribution ports; a hydraulic follow-up cylinder having a double acting duplicating piston connected serially in one of said lines; and a differential control lever positively connected to said valve plunger and said duplicating piston and arranged to impart operating movements to said valve plunger and to receive follow-up movements from said duplicating piston; and automatic valve means openable only at the ends of the stroke of the servo piston for coordinating the movements of said control lever

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and said servo piston, whereby the position of said control lever continuously controls the pitch of the said blades.

4. A controllable pitch marine propeller system adapted to be energized from a power source of liquid having a high pressure outlet and a low pressure inlet, comprising in combination: a tubular propeller shaft; a hollow hub affixed tightly to one end of said shaft and having axially turnable blades mounted thereon; blade turning mechanism in said hub comprising a hydraulic servo motor having two chambers, a rodless servo piston displaceable by differential liquid pressure in said chambers, and a mechanical movement positively connecting said servo piston to said blades, thereby to turn said blades axially in unison to change their pitch upon displacement of said servo piston; a stationary liquid control valve having an intake port and an exhaust port adapted for connection to said outlet and said inlet respectively, two distribution ports, and a valve plunger of open-center type for controlling the passage of liquid through said ports and settable in opposite directions from a neutral position wherein liquid can pass from said intake port to said exhaust port; a stationary hydraulic cylinder having two chambers, one of which has a displacement capacity equal to the displacement capacity of one of the chambers of said servo motor, and a duplicating piston with a rod projecting from said cylinder; a continuous hydraulic connection between said chambers of equal displacement capacity, a hydraulic connection between the other of said servo motor chambers and one of said distribution ports, and a hydraulic connection between the other of said cylinder chambers and the other said distribution port, whereby said servo motor and said hydraulic cylinder are hydraulically connected in series between said distribution ports and can be actuated reversibly by displacement of said valve plunger in one direction or the other away from neutral setting; a pitch control member operatively connected to said valve plunger and said piston rod, whereby direct movement is imparted to said valve plunger by said control member and follow-up movement is imparted to said valve plunger and said control member by said piston rod; semi-automatic hydraulic means, including calibrating valve means operatively associated with said servo piston and openable only at the ends of the stroke thereof, for regulating the quantity of liquid operatively interconnecting said servo piston and said duplicating piston, whereby the relative positions thereof are coordinated so as to ensure duplicate movements thereof; and locking valve means in the hydraulic connections to said distribution ports and actuated by displacement of said valve plunger from neutral for hydraulically locking the servo piston and duplicating piston while the valve plunger is in neutral; whereby the position of said control member sets and indicates the pitch of said blades and said blades are hydraulically locked in any pitch to which they may be set by said member.

5. In a controllable pitch marine propeller system including a propeller having a hollow hub with blades mounted for angular pitch change; power mechanism for controlling and indicating the pitch of said blades comprising in combination: a double-acting liquid-operated servo motor comprising a cylinder within said hub having two chambers for liquid and a servo piston displaceable in opposite directions in said cylinder by transfer of liquid under pressure into the respective chambers; mechanical means in said hub positively connecting said piston to said blades so as to change the angle of said blades in unison upon displacement of said servo piston; a hydraulic cylinder having two chambers for liquid, one of which has a displacement capacity equal to the displacement capacity of one of said servo motor chambers, and a duplicating piston displaceable in said hydraulic cylinder according to the volume of liquid in said equal

capacity chamber; a power source of pressure liquid; a stationary control valve for said liquid, connected in a hydraulic circuit with said source, having a movable valve member and two pressure liquid distribution ports; a continuous hydraulic connection between said chambers of equal capacity, a hydraulic connection between the other chamber of said servo motor and one of said ports, and a hydraulic connection between the other chamber of said hydraulic cylinder and the other of said ports, whereby said servo motor and said cylinder are hydraulically connected in series and are reversibly controlled by said valve member; a position control member positively connected to said duplicating piston and said valve member, whereby direct motion is imparted to the valve member upon operation of the control member and follow-up motion is imparted to the control member and valve member upon displacement of the duplicating piston: normally closed calibrating valve means for regulating the transfer of fluid between the two chambers of said servo motor and operable only by said servo piston at the ends of its stroke, thereby to transfer fluid sufficient to coordinate the relative positions of said servo piston and said duplicating piston so that they perform duplicate movements; whereby the position of said control member controls the pitch of said blades; and means operatively associated with said control member for indicating the pitch of said blades.

6. In a hydraulically actuated controllable pitch propeller system, the combination comprising a hollow shaft carrying a propeller having blades rotatably mounted for pitch changing movements; mechanism for changing the pitch of said blades including a servo motor having a servo piston positively connected to said blades; a power source of hydraulic pressure fluid having a pressure fluid outlet and a return fluid inlet; a servo valve having intake, exhaust and two distribution valve ports and a movable valve plunger for controlling the passage of fluid through said ports, said intake and exhaust ports being hydraulically connected to said outlet and inlet respectively; two hydraulic connections between said servo motor and the two distribution ports of said servo valve;

a hydraulic motor having a cylinder connected serially with said servo motor in one of said hydraulic connections and a duplicating piston reciprocable in said cylinder; fluid locking valve means hydraulically connected in both said connections; a pitch control member constituting a differential lever connected to impart direct movement to said valve plunger and to receive follow-up movement from said duplicating piston; pitch indicating means associated with said control member; and calibrating valve means in said servo piston for passing fluid through said servo piston only at each end of its stroke; whereby the position of said control member controls the position of said servo piston and indicates the set pitch of said blades, and the blades are locked hydraulically in the set pitch.

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