Dec. 14, 1965 J. MERCIER ETAL 3,223,382

HYDRAULIC CONTROL SYSTEM

Filed April 20, 1964 2 Sheets-Sheet 1

FIG. 1

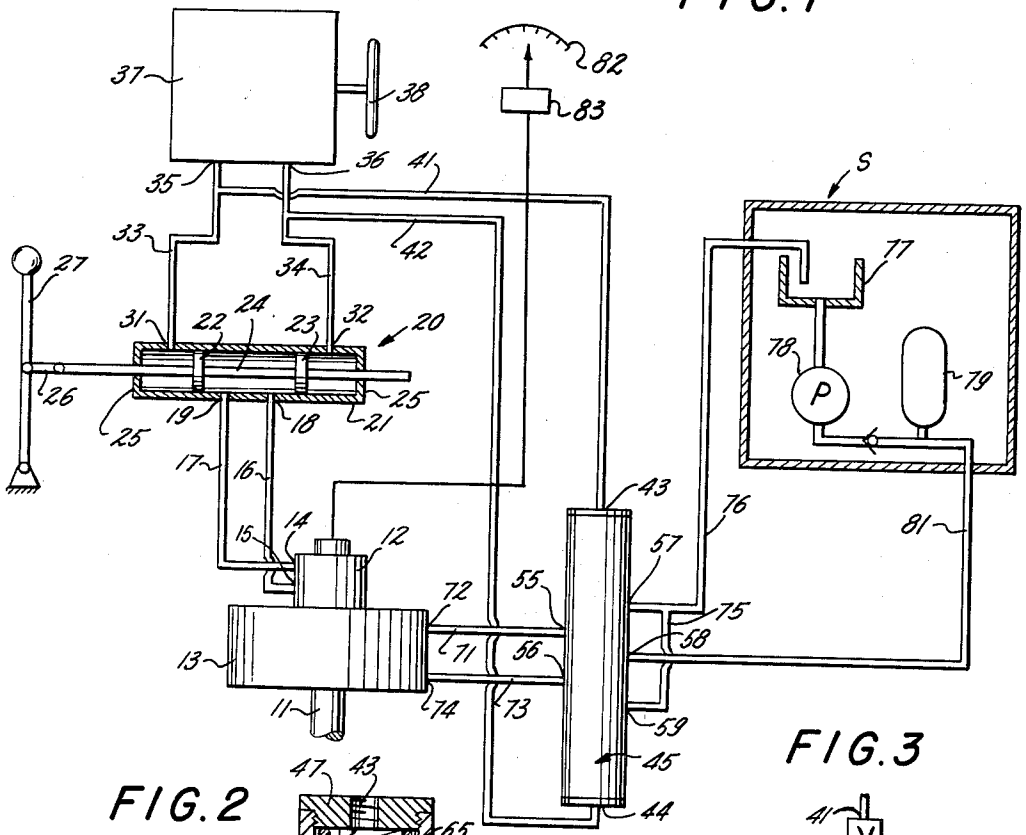


FIG. 2

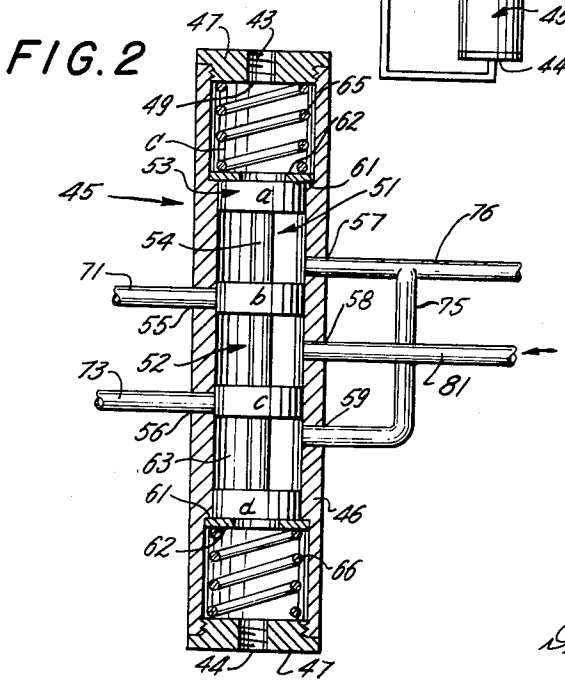
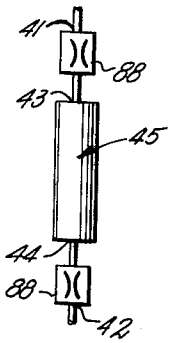


FIG. 3



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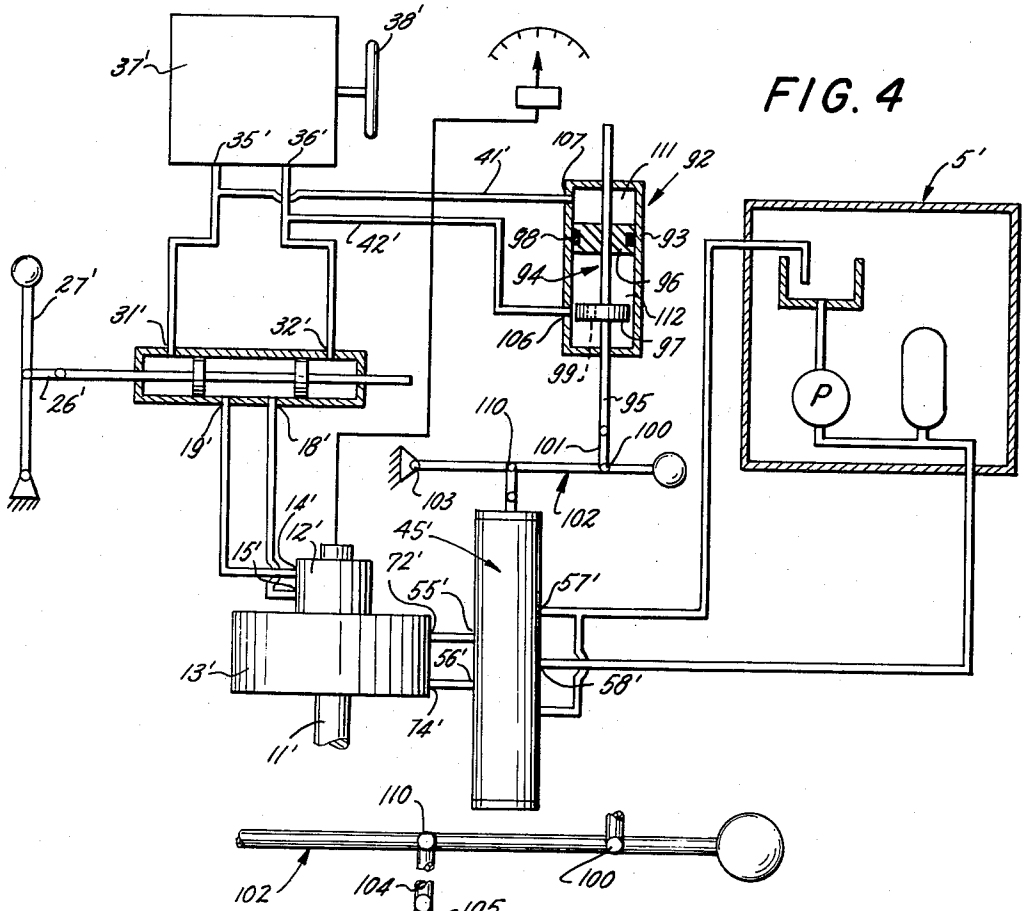


FIG. 4

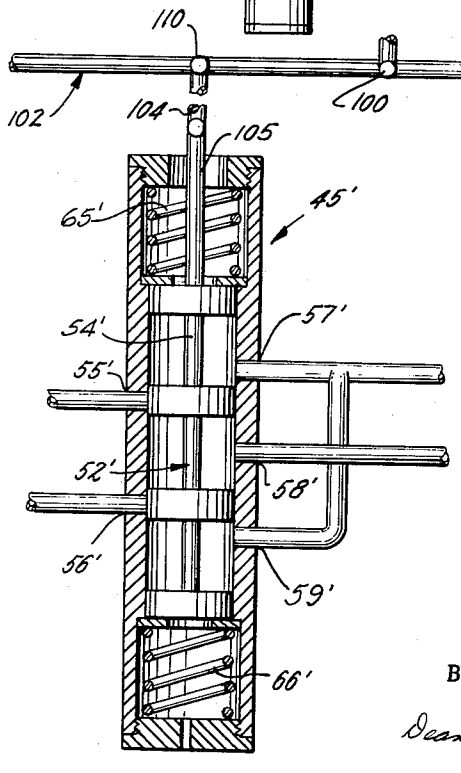


FIG. 5

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HYDRAULIC CONTROL SYSTEM

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This invention relates to the art of hydraulic control systems, more particularly of the type to effect remote control of the rudder shaft of a ship.

As conducive to an understanding of the invention it is noted that the rudder shaft of a ship, especially when the ship is large, requires considerable force for actuation thereof through an appreciable range of movement and with sufficient rapidity to take care of emergencies when the course of the ship must be rapidly changed. Where such force is supplied by a high torque hydraulic motor operatively connected to the rudder shaft and which is energized by a power source having a motor driven pump which feeds the motor, due to the kinetic energy of the heavy moving rudder, even when the power source is turned off, the rudder continues its movement for an additional amount.

This additional movement, although not critical when the ship is on the high seas with ample room in which to maneuver, can be extremely dangerous when the ship is in a confined area such as when it is in a harbor.

It is accordingly among the objects of the invention to provide a hydraulic control system which is relatively simple in construction and dependable in operation, and which will provide both rapid movement of the rudder shaft of a ship over an appreciable range and with a simple control operation will also provide step by step movement of the rudder with substantially no overshoot from the desired setting of the rudder with controllable variations in the rate at which such step by step movement can be effected and which will also permit manual operation of the rudder in the event that the motor driven power source thereof fails.

According to the invention, these objects are accomplished by the arrangement and combination of elements hereinafter described and more particularly recited in the claims.

In the accompanying drawings in which are shown one or more of various possible embodiments of the several features of the invention,

FIG. 1 is a diagrammatic view of one embodiment of the invention,

FIG. 2 is a longitudinal sectional view of a control valve utilized in the embodiment of FIG. 1,

FIG. 3 is a modification of the embodiment of FIG. 1,

FIG. 4 is a view similar to FIG. 1 of another embodiment of the invention, and

FIG. 5 is a longitudinal sectional view of a control valve utilized in the embodiment of FIG. 4.

Referring now to the drawings, the hydraulic equipment shown in FIG. 1 is designed to control the rudder shaft 11 of a ship.

To this end the shaft 11 has secured thereto hydraulic motors 12 and 13 which may be of the type put out by Houdaille Industries, Inc., of Buffalo, New York, under the trademark HYD-RO-AC, the motor 13 having a greater torque output than motor 12 for example, in the order of say ten to one.

The motor 12 has pressure ports 14 and 15 connected by lines 16 and 17 to the ports 18 and 19 of a control valve 20. The control valve 20 comprises a cylinder 21 having two spaced pistons 22 and 23 therein, mounted on a piston rod 24 which extends axially through the cylinder 21 and through the opposed ends 25 thereof, suitable seals (not shown) being provided in such ends.

One of the protruding ends of the piston rod 24 is pivotally connected by a link 26 to a pivoted control lever 27 for manual operation of the control valve 20.

Movement of the control lever 27 provides two different connections for the ports of the valve 20; in the neutral position shown, the ports 18 and 19 of valve 20 are in communication with each other through the annular chamber provided between the two pistons and when the lever is moved either to the left or right, the port 19 will be connected to port 31 and the port 18 will be connected to port 32. The ports 31 and 32 are connected by lines 33, 34 to the ports 35, 36 of a telemotor 37 which has a steering wheel 38 associated therewith.

The telemotor is of conventional type and includes a volumetric pump and a fluid reservoir so that based on a given angular rotation of the steering wheel 38 a given output will be provided.

In the illustrative embodiment herein shown, the steering wheel is connected through a step-down gear mechanism to the pump so that 360° rotation of the steering wheel will be related to a volumetric fluid output of the pump that will provide sufficient flow at the required pressure to effect rotation of the motor 12 to turn the rudder shaft 11, say 18°.

As such telemotor construction including the gear mechanism and volumetric pump are well known in the art they will not be further described.

The lines 33, 34 are also connected by lines 41, 42 to the control ports 43, 44 at the respective ends of a four-way hydraulic control valve 45.

The control valve as shown in FIG. 2, comprises a cylindrical casing 46 having plugs 47 at each end with axial passageways 49 to the outer ends of which the ports 43, 44 are connected.

Positioned in the bore 51 of the control valve is a control valve member 52 which has four spaced pistons 53*a*, *b*, *c*, *d* mounted on an axial rod 54. The control valve has ports 55, 56, 57, 58 and 59. The bore of valve 45 has an annular shoulder 61 adjacent each end on which is seated a washer 62, the inner diameter of the washer being less than the diameter of the central portion 63 of the bore 51. The washers are retained on the shoulders by tensed coil springs 65, 66 compressed between the washer and the end of the adjacent plug 47. The valve member 52 is of length substantially equal to the longitudinal distance between the shoulders 61 so that when no pressure is applied to either of the control ports 43, 44, the valve member will be in the neutral position shown in which the two central pistons 53*b* and 53*c* will close ports 55, 56 and the ports 57, 58, 59 will lead into the annular spaces between the adjacent pistons 53*a* to 53*d*. The control port 55 is connected by line 71 to the port 72 of motor 13 and the control port 56 is connected by line 73 to the port 74 of motor 13. The ports 57 and 59 are connected together by line 75 and also by line 76 to the reservoir 77 of the pressure source S. The pressure source includes a conventional motor driven pump 78 with an associated pressure accumulator 79 and the fluid

port of the pressure accumulator and outlet port of the pump 72 are connected by line 81 to port 58 of the valve.

In the operation of the equipment shown in FIGS. 1 and 2, assuming that the ship is on the high seas with ample space to navigate, the helmsman will set the lever 27 to the neutral position shown in FIG. 1 in which the ports 14 and 15 of motor 12 are short circuited and the ports 31, 32 of the valve 20 are blocked. As a result, the motor 12 will not be in circuit.

To steer the ship, the helmsman need merely turn the steering wheel 38 in direction to effect the desired movement of the rudder until the steering wheel can no longer be turned. It is to be noted that since the port 35, for example of the telemotor, through which fluid will flow, is connected to port 43 of the valve 45, the amount of fluid that can enter such valve is determined by the volume of the chamber C defined between the port 43 and the piston 53*a* when the latter has moved to its bottommost position due to the fluid pressure applied to port 43.

Consequently, it is clear that only a slight amount of fluid can flow into such chamber C based on its volumetric capacity and the helmsman would only have to rotate the steering wheel a small amount, illustratively say, 10° which would be related to the volume of such chamber C. When the chamber C has been charged with fluid it will be noted that there will be resistance provided by the compression of the coil spring 66 which, acting on the valve member 52, will provide a resilient force against the body of fluid in chamber C and in the line 41 leading to the telemotor 37. The spring when compressed, illustratively is designed to provide a force against the valve member 52 that will create a pressure of say 10 atmospheres on the body of fluid in the chamber C and line 41.

As a result of such action by the helmsman which effected downward movement of the valve member 52, the ports 58 and 56 of the valve member 45 will be connected so that fluid under pressure from the source S will be forced into the port 74 of motor 13 to cause the shaft 11 thereof to rotate, return of fluid from the motor being effected from port 72 through line 71, port 55 of the valve 45, port 57 and line 76 to the reservoir 77.

So long as the helmsman retains pressure on the steering wheel 38, the valve member 52 will remain in the position described and there will be continued flow of fluid under pressure from source S to the motor 13 to effect rotation of the rudder.

When the helmsman by viewing an indicator 82 driven in conventional manner through a suitable servo-system 83 from the rudder shaft 11, sees that the rudder has turned the desired amount, he need merely release pressure on the steering wheel. As such servo-indicator system is conventional and forms no part of this invention, it will not be further described.

As a result of the force exerted by the compressed spring 66, the fluid in chamber C and line 41 will be forced in reverse direction into port 35 of the telemotor through the pump of the telemotor and from port 36 of the telemotor and line 42 into port 44 of the control valve 45. As a result, the valve member 52 will move upwardly under the force exerted by spring 66 until the upper piston 53*a* abuts against the upper washer 62. Since, at this time both of the springs 65, 66 will now be restrained by the abutment of washer 62 against shoulder 61 and since no further fluid under pressure is forced through either of the ports 43, 44, the valve member 52 will remain in neutral position with ports 55, 56 blocked.

As a result, there will be no further flow of fluid under pressure to the motor 13 and the rudder shaft will stop rotating and be retained in the angular position reached at such time.

To turn the rudder to neutral position in which it will be longitudinally aligned with the ship, the helmsman need merely rotate the steering wheel in the opposite direction, say 10° and the action above described will repeat in reverse direction and when the indicator shows that the rudder is in neutral position the helmsman need merely release the steering wheel which will automatically return to the neutral position due to the volume of fluid forced in reverse direction through the volumetric pump.

In the event, for some reason, that the motor driven pressure source S should fail, steering action can still be effected.

In such case, the helmsman need merely move the lever 27 of valve 20 to connect ports 31, 19 and 32, 18 so that the motor 12 is in circuit.

Thereupon, by rotating the steering wheel in the direction desired for desired movement of the rudder, say in the direction to force fluid under pressure through port 35 a quantity of oil under pressure will be forced into the motor 12 to provide the desired steering action although at a much slower rate than would be effected by the motor 13 due to the fact that its torque output is considerably greater than that of motor 12. The reason that the motor 12 is of smaller torque output is that insufficient quantity of oil could be supplied to the motor in a short period of time for rapid movement of the rudder shaft unless the pump in the telemotor was of very large size which would require more power than could be manually supplied by a helmsman.

Due to the fact that the pressure in line 33, for example, will rise, when the steering wheel 38 is rotated, to an amount above 10 atmospheres and as such pressure will be applied to port 43 of valve 45, the valve member 52 thereof will move downwardly.

Hence as above described, ports 55 and 56 will be connected to ports 57, 58 respectively of valve 45 to provide a path for the fluid to flow out of motor 13 into the reservoir 77. In the absence of such a path, since the hydraulic circuits into and out of motor 13 would be blocked, the motor 13 could not rotate freely thereby restraining free rotation of motor 12.

The operation of the equipment as above described with valve 20 in neutral position, though completely satisfactory and desirable when the ship has large areas in which to maneuver, raises certain problems when the ship must maneuver in a small area such as in a harbor when it is being docked. Thus, it is to be noted that with valve 20 in neutral position, when the steering action is effected by a slight rotation, i.e., 10° of the steering wheel, with the motor 12 short circuited, when the helmsman sees on his indicator 82 that the rudder is reaching the desired position, he must release the steering wheel before the desired position is reached due to the fact that the kinetic energy developed by the moving rudder will continue to move the rudder slightly even after flow of fluid to the motor 13 has ceased. Consequently, if the helmsman releases the steering wheel at the exact desired position of the rudder, the rudder will overshoot which is extremely dangerous in confined areas.

The equipment above described is universal in its application in that coarse steering is provided on the high seas and fine steering may be provided in confined spaces by merely moving the lever 27 of valve 20 to connect ports 19, 31 and 18, 32 so that the motor 12 is in circuit.

With the motor 12 in circuit the steering operation is as follows:

When the helmsman rotates the steering wheel 38, fluid under pressure will flow through line 41, for example, to control port 43 of valve 45 and also through ports 31 and 19 of valve 20 to port 14 of motor 12, return for said motor being from port 15 thereof through ports 18 and 32 of valve 20 to port 36 of the telemotor.

As previously described, due to the small volume of chamber C of valve 45, a slight rotation in the order of 10° of the steering wheel will move the valve member 52 of valve 45 to its lowermost position against the tension of coil spring 66 thereby connecting the pressure source S to port 74 of motor 13 so that said motor 13 will

rotate the shaft 11 thereof and also cause the shaft of motor 12 to rotate in the same direction. Due to the rotation of motor 12, cavitation in lines 17 and 33 will cause the pressure in line 41 to drop whereupon the tensed spring 66 of valve 45 will move the valve member 52 thereof upwardly to closed position, thereby blocking further flow to the motor 13.

Thus, with initial 10° rotation of the steering wheel, the rudder would only be moved a very slight amount, say one-half degree. At this time, since the valve 45 is in closed position, the ports 72, 74 of motor 13 are blocked which would prevent rotation of the shaft 11. Continued rotation of the steering wheel, say, another 10°, will again cause the valve 45 to be actuated to move the rudder shaft another one-half degree before drop in pressure in line 41 again closed valve 45.

It is apparent from the foregoing that since each 10° rotation of the steering wheel effects one-half degree rotation of the rudder shaft, by continuous rotation of the steering wheel incremental movements in slight steps of the rudder is effected. Consequently, as the helmsman is rotating the steering wheel slowly, there is a step by step movement of the rudder shaft by small incremental amounts of one-half degree with a lapse between each incremental movement required to permit the pressure in line 41 to build up sufficiently to overcome the force of the spring 66 so that the valve member can move to open position.

It is apparent therefore, that if the helmsman stops such slow rotation of the steering wheel at any time, there will be extremely small overshoot, i.e., only a fraction of the one-half degree step which provides extremely precise maneuverability for confined areas.

This is to be contrasted with the rapid movement of the rudder shaft 11 effected when the pressure is applied continuously rather than in steps which causes the motor 13 to rotate continuously which rotation when transferred to the heavy rudder, causes the rudder to continue swinging.

The universality of the system is apparent from the fact that even with the system set up for step by step movement of the rudder, the speed or rate of the step movements can be increased by the helmsman as desired by more rapid turning of the steering wheel. Thus, absolute control is possible in confined quarters, i.e., slow step by step movement of the rudder or step movements at a higher rate of speed at which, even though there may be some overshoot, it will still be extremely small and controllable.

With the step by step motion above described, it is apparent that due to the variation in pressure in the lines leading to the control valve 45 and the motor 13, pulsations are caused in such lines which may possibly cause hammer shock with resultant fatigue and rupture. This problem becomes serious in large ships where the kinetic energy due to the movement of the large rudder is extremely great. Accordingly, to solve this problem in large ships, the embodiment shown in FIG. 3 may be utilized which is identical to that shown in FIGS. 1 and 2 except that a restricted orifice 88 is provided in the lines leading to the control ports 43 and 44 of valve 45. As a result of such restricted orifice, even with drop in pressure in lines 41 and 42 due to the rotation of the small motor 12, the effect of such reduced pressure on the control valve member 52 of valve 45 is delayed so that the blocking of fluid under pressure from the control source S does not occur as quickly, but gradually is reduced as the outlet ports are closed by the slow movement of the valve member.

In situations where there may be extreme variations in temperature such as encountered in the tropics between day and night where the temperature may drop as much as 40° and also when the ship is traveling through different temperature zones, the viscosity of the oil used in the hydraulic system may change so that the restricted orifice 88 would have to be adjusted in order for dependable operation to be effected. To avoid the need for adjustment, the embodiment shown in FIGS. 4 and 5 may be used.

In this embodiment in which parts corresponding to those in FIGS. 1 and 2 have the same reference numerals primed, the single control valve 45 is replaced by valve 45′ and hydraulic actuator 92, the valve 45′ being identical to the valve 45 shown in FIG. 2 except that it is mechanically operated and does not utilize the control ports.

The actuator 92 comprises a cyclindrical casing 93 which has a valve member 94 therein comprising a piston rod 95 extending through both ends of the casing, suitable seals (not shown) being provided to prevent leakage. The piston rod 95 has two spaced pistons 96, 97 secured thereto, the piston 96 being in sliding engagement with the bore of casing 93, resilient rings 98 encompassing said piston 96 to define a seal.

The piston 97 is of slightly smaller diameter than the bore of casing 93 to provide clearance between the periphery of the piston 97 and the casing wall, and in the illustrative embodiment shown small diameter passageways 99 are provided through said piston 97.

The lower end of piston rod 95 is connected through a link 101 as at 100 to a control lever 102 adjacent one end thereof. The other end of the lever is pivotally connected to a fixed support as at 103 and the portion of the lever 102 between its ends is pivotally connected as at 110 through a link 104 to an extension 105 of the piston rod 54′ of valve 45′.

With the valve member 52′ of valve 45′ retained in its neutral position by springs 65′, 66′, the valve member 94 of actuator 92 will be retained through the linkage 105, 104, 102, 101, 95, in the neutral position shown in FIG. 4. Thus, the piston 97 will be aligned with port 106 connected by line 42′ to port 36′ of telemotor 37′, and the piston 96 will be spaced from port 107 connected by line 41′ to port 35′ of the telemotor 37′.

In the operation of the embodiment shown in FIGS. 4 and 5 when the helmsman rotates the steering wheel 38′, fluid under pressure will, for example, be applied to port 107 of actuator 92 causing the valve member 94 thereof to move downwardly. As a result, the fluid beneath the piston 96 will flow through port 106 back to port 36′ of the telemotor 37′. Downward movement of member 94 of actuator 92 will pivot lever 102 and move the valve member 52′ of valve 45′ to connect ports 58′, 56′ and 57′, 55′ so that fluid under pressure will flow from pressure source S to port 74′ of the hydraulic motor 13′, thereby rotating the rudder shaft 11′ and motor 12′. Assuming that lever 27′ is in the position to connect ports 19′, 31′ and 18′, 32′ so that motor 12′ is in circuit, rotation of motor 12′ will cause a drop in the pressure in line 41′ so that the tensed spring 66′ of valve 45′ will urge the valve member 52′ thereof upwardly. However, due to the dashpot action provided between the lower piston 97 and the bottom of the casing 93 of actuator 92, the speed of such upward movement of valve member 52′ is restricted and in fact some means must be provided to enable the movement to occur in a reasonable period of time. This is accomplished in the illustrative embodiment shown by having the slight clearance above mentioned between the periphery of the lower piston 97 and the wall of the actuator 92 and in addition, the small diameter passageways 99 afford further relief of the dashpot action.

As a result of such dashpot action, it is apparent that the valve member 52′ of valve 45′ will move slowly toward closed position and hence the flow of fluid under pressure from the pressure source S′ to motor 13′ will be cut off gradually to avoid the sharp impact that would be effected by rapid cutoff.

The rate of movement of the piston rod 95 of actuator 92 is not linear but it is greatly slowed down as the lower piston 97 reaches the port 106 for at such time the rate

of flow into such port is greatly reduced due to the narrow clearance between the wall of the actuator 92 and the piston 97. Since the rate of flow from the upper chamber 111 of the actuator 92 is determined by the rate of flow into the lower chamber 112 through port 106, it is apparent that as the valve member 52' of valve 45' approaches neutral position or cutoff of flow from the pressure source S' such cutoff will be extremely gradual.

It is to be noted that by merely increasing the distance between the pivot point 110 of lever 102 and the connection of piston rod 95 thereto at 100, a reduction can be achieved between the length of stroke of the piston rod 95 of actuator 92 and the stroke of the valve member 52'. As a result, large movement of the actuator 92 can be made to provide very small movement of the valve member 52' thereby further slowing the rate of opening and closing of the valve member 52' and hence the application of pressure from the pressure source S'.

It is apparent that this dashpot action works both during the opening of the valve 45' and the closing of the valve 45' so that the impact of the fluid under pressure from the pressure source is reduced at time of application and at time of cutoff.

The equipment above described also permits hand operation at a remote position adjacent the rudder by merely having a crew member manually actuate the lever 102.

As many changes could be made in the above systems and many apparently widely different embodiments of this invention could be made without departing from the scope of the claims, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

Having thus described our invention, what we claim as new and desire to secure by Letters Patent of the United States is.

1. A hydraulic control system for effecting rotary movement of a shaft on each side of a neutral position, comprising a hydraulic motor operatively connected to said shaft to rotate the latter, said motor having control ports, a valve having control ports connected to the control ports of said motor, said valve having a fluid pressure inlet port and a return port, a source of fluid under pressure connected to said pressure inlet port and adapted to provide a constant source of pressure thereto, a reservoir connected to said return port, a second source of fluid under pressure adapted to supply fluid under pressure only when actuated, said valve having a valve member, resilient means reacting against said valve member normally retaining the latter in neutral position to block said control ports and said inlet and return ports and means operatively connecting said second source to said valve to effect movement of said valve member to operative position upon actuation of said second source thereby to connect said control ports to said inlet port and said return port to actuate said hydraulic motor.

2. The combination set forth in claim 1 in which means are provided alternative to move said valve member between neutral position and operative position as said second source is being actuated for intermittent application of fluid under pressure from said first source to said motor.

3. A hydraulic control system for effecting rotary movement of a shaft on each side of a neutral position, comprising a hydraulic motor operatively connected to said shaft to rotate the latter, means to provide a constant source of fluid under pressure to said motor, a second source of fluid under pressure adapted to supply fluid under pressure only when actuated, valve means interposed between said constant source of fluid and said motor, said valve means having a neutral position in which said constant source is cut off from said motor and an actuated position in which said constant source is connected to said motor, means controlled by the actuation of said second source to move said valve means from neutral position to actuated position to effect rotation of said shaft by said motor and means controlled by rotation of said motor to effect movement of the valve means to neutral position, said means comprising a second hydraulic motor operatively connected to said shaft, valve means alternately to connect said second motor to said second source and to short circuit said second motor, said first valve means being movable between its two positions by the application of pressure thereto from said second source, and means resiliently urging said valve means to neutral position whereby when said second motor is connected to said second source, rotation thereof by said first motor will cause the pressure to said valve means to drop, whereby the resilient means will restore the valve means to closed position.

4. A hydraulic control system for effecting rotary movement of a shaft on each side of a neutral position, comprising a pair of hydraulic motors operatively connected to said shaft to rotate the latter, each of said motors having a pair of control ports, a valve having control ports connected to the control ports of one of said motors, said valve having a fluid pressure inlet port and a return port, said valve having a valve member, resilient means normally retaining said valve member in neutral position to block said control ports and said inlet and return ports, a first source of fluid under pressure connected to said pressure inlet port and adapted to provide a constant source of pressure thereto, a reservoir connected to said return port, a second source of fluid under pressure, valve means interposed between said second source and said other motor, said valve means having a first position in which said second source is connected to said other motor and a second position in which said other motor is short circuited, said second source only supplying fluid under pressure when actuated, and means operatively connecting said second source to said first valve to effect movement of the valve member thereof upon actuation of said second source, thereby to connect said first source to said first motor.

5. The combination set forth in claim 4 in which said valve comprises a casing in which said valve member is slidably mounted, said valve member having end portions, said resilient means reacting against each of the end portions normally to retain the valve member in neutral position, a pair of fluid ports leading respectively into opposed ends of said casing, said second source of pressure being connected to said fluid ports to react against the respective end ports of the valve member.

6. The combination set forth in claim 1 in which said valve comprises a casing in which said valve member is slidably mounted, said resilient means reacting against said valve member in opposed directions normally to retain the valve member in neutral position, an actuator is provided comprising a casing having a piston slidable therein, said actuator casing having a port on each side of said piston, said ports being connected respectively to said second source of pressure, a piston rod extending longitudinally through said actuator casing and mounting said piston, a second piston secured to said piston rod, said second piston having its periphery slightly spaced from the wall of said actuator casing to define a dashpot, said piston rod being operatively connected to said valve member to effect movement thereof.

7. The combination set forth in claim 4 in which a lever is provided pivotally mounted at one end to a fixed support, said piston rod being pivotally connected at one end to said lever and said valve member being pivotally connected at one end to said lever between the pivotal mount thereof and the connection of the piston rod thereto.

8. The combination set forth in claim 4 in which said motors are of the rotary type and are axially aligned with said shaft.

9. The combination set forth in claim 4 in which means are provided to restrict the rate of movement of said valve member.

10. The combination set forth in claim 4 in which means are provided to restrict the rate of movement of said valve member as the latter approaches and moves away from neutral position.

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