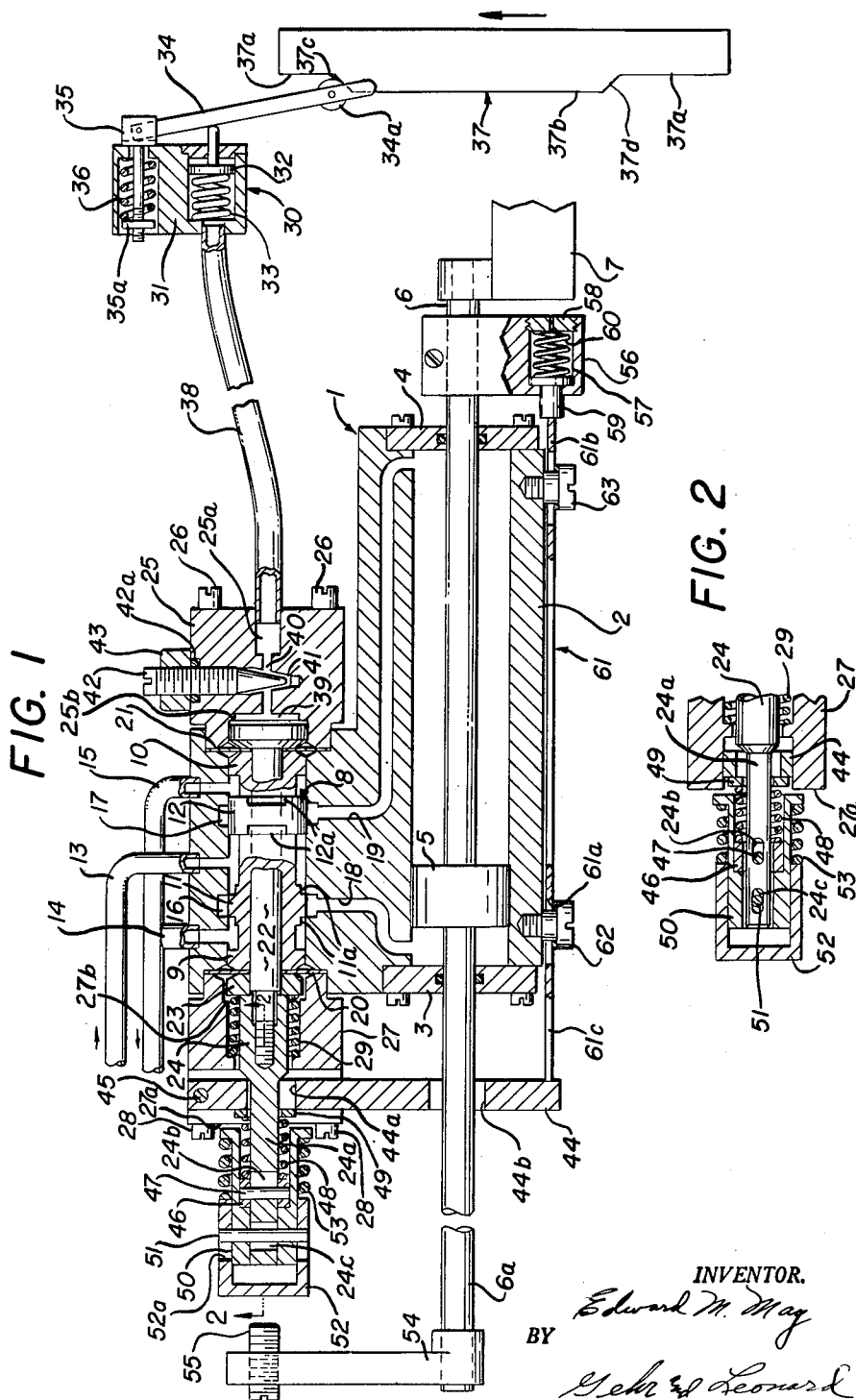


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TRANSMITTER-CONTROLLED HYDRAULIC SERVOMOTOR
WITH AUTOMATIC STOP MEANS
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TRANSMITTER-CONTROLLED HYDRAULIC SERVOMOTOR WITH AUTOMATIC STOP MEANS

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3 Claims. (Cl. 121-45)

The invention relates to hydraulic transmitter-controlled servomotor apparatus.

In such apparatus the admission and exhaust of working fluid to and from the servomotor is controlled by a valve, usually of the cylindrical or spool type, which has a transverse pressure surface exposed to a receiver chamber that is connected through suitable conduit means with a fluid pressure transmitter which may be actuated either manually or by some automatic means. In addition, means for exerting a biasing force on the valve in opposition to the transmitter is provided in the form of fluid pressure, a spring, or other equivalent means.

In such prior apparatus it has not been possible to control the stopping of the hydraulic motor with desired accuracy and freedom from hunting and vibration, particularly where the moving part of the motor and the body driven by it are of large weight and/or move at high speed.

Accordingly applications of such motor apparatus have been correspondingly limited.

It is an object of the present invention to provide a hydraulic transmitter-controlled servomotor apparatus which is capable of stopping without hunting and which comprises improved stop devices operatively associated with the motor control valve which are adapted to stop a heavy body driven by the motor at relatively high speed and position the body with a high degree of accuracy.

Another object of the invention is to provide transmitter-controlled hydraulic servomotor mechanism such as last referred to which is adapted to stop accurately bodies of widely different weights without the necessity of special adjustments in the apparatus to compensate for the variations of load weight.

A further object of the invention is to provide a transmitter-controlled hydraulic servomotor having automatic control means for the motor valve adapted to effect gradual application of a stopping force to the moving part of the motor by setting up a dash-pot action between the motor displacement member and its working chamber amplified by discharge of the dash-pot fluid against the inlet pressure of the motor fluid, with resultant quick stopping without shock.

Other objects and means for attaining them which are more or less ancillary or incidental to the above-noted objects will hereinafter appear.

With the stated objects in view the invention consists in certain forms, arrangements and combinations of parts which are exemplified in the apparatus shown in the accompanying drawing and will now be described, explained and particularly pointed out in the appended claims.

In the accompanying drawing,

Fig. 1 is a longitudinal sectional view of a transmitter-controlled servomotor apparatus, the showing of conventional parts of the apparatus which cooperate with the motor being, to some extent, diagrammatic in character.

Fig. 2 is a fragmentary sectional view taken on the line 2-2 of Fig. 1.

Referring in detail to the construction illustrated, 1 generally designates a servomotor having relatively movable power elements consisting of a fixed cylinder block 2 with a main bore closed by heads 3 and 4 and a movable piston 5 mounted in the cylinder bore. The piston has a rod 6 to which is connected a part 7 of a device to be driven or controlled, such for example, as the movable

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work table of a boring mill or the tool carriage of a lathe.

The cylinder block is formed with a second bore to receive the slidably mounted control valve generally designated by the numeral 8. Valve 8 is generally cylindrical in form and has circumferential grooves forming head sections 9 and 10 and active valve lands 11 and 12. A fluid pressure supply conduit 13 is arranged to communicate with the valve groove between the lands 11 and 12, while exhaust conduits 14, 15 communicate with the valve grooves between the respective heads and adjacent lands of the valve. The lands 11 and 12 cooperate in well known manner with annular grooves 16 and 17 in the walls of the block structure and these annular grooves communicate through conduits 18 and 19 with the respective ends of the piston bore of the cylinder.

As shown, the valve lands 11 and 12 are wider than their cooperating annular grooves 16 and 17 and are formed with circumferentially extending port notches 11a and 12a, the axial width of the notches being such that the part of each land between opposite notches is of substantially the same axial width as its cooperating groove 16, or 17, and serves to cover the annular groove or port when the valve is in its neutral or closed position.

Hydraulic packings between the valve bore of the cylinder block and the ends of valve 8 are provided by annular diaphragms 20 and 21 of flexible sheet material, the inner edge of diaphragm 21 being clamped to the head 10 of the valve by the head of a bolt 22 extending through the valve body axially while the inner edge of diaphragm 20 is secured to the other head 9 of the valve by washer 23 and nut 24. The outer edge of the diaphragm 21 is secured to the cylinder block by means of a rigid clamping block 25 which is removably connected to the cylinder block by screws 26, 26. In similar manner the periphery of diaphragm 20 is secured to the cylinder block by clamping block 27 which is connected to the cylinder block by screws 28, 28.

A biasing spring 29 interposed between the washer 23 and a shoulder formed in the bore of block 27 urges valve 8 toward the right. Full open positions of the valve are limited by stop shoulders 27b and 25b.

The numeral 30 generally designates a diagrammatically shown hydraulic transmitter mechanism of the character fully disclosed in my U. S. Patents Nos. 2,607,196 and 2,580,686. It comprises a cylinder 31 in which is mounted a piston 32 subject to the biasing effect of a spring 33, together with a piston actuating lever 34 pivotally mounted in the slotted head of a bolt 35 which has a swivel mounting in the cylinder block 31 and is held yieldingly in normal working position by a coil spring 36. Tension of spring 36 can be adjusted by nut 35a to provide a working tension of the spring greater than the tension of the biasing spring 29 of the motor valve. This mounting of the pivot bolt permits its limited axial movement against the tension of the spring.

The actuating lever 34 is arranged to be driven by a movably mounted timer cam 37, the lever being fitted with an anti-friction roller 34a which engages the active edge surface of the cam and serves as a follower therefor. The cam, shown diagrammatically in flat form, may be mounted for movement in any suitable manner but preferably is formed of flexible sheet material and bent around a rotary support cylinder, as shown in U. S. Patent No. 2,607,196, the supporting cylinder being motor driven and constructed to carry a plurality of cams to effect the driving of a plurality of transmitters in timed relation to each other. For the purposes of the present invention the cam 37 is formed with active surfaces including longitudinal base surfaces 37a, longitudinal top surface 37b and sloping surfaces 37c, 37d, which connect the longitudinal surfaces.

It will be seen that this timer cam serves only to open valve 8 in either direction, slope 37c opening the valve to the left and slope 37d allowing spring 29 to open it to the right. The slopes do not exercise any modulating effect on the valve.

The cylinder 31 of the transmitter communicates through a conduit 38 with a passage 25a formed in the outer end of the clamping block 25. The inner end of

block 25 is formed with a recess the walls of which together with diaphragm 21 and the head of bolt 22 form a receiver chamber 39. This chamber communicates with the passage 25a and conduit 38 through a restrictor passage 40 of rather small diameter. Passage 40 is intersected at right angles by a tapered hole 41 of larger diameter than the passage and in this hole is arranged the correspondingly tapered end of an adjustable screw 42. The screw is fitted with a lock nut 43 which serves to secure it in any desired position of adjustment in relation to the wall of the tapered hole 41. A packing ring 42a prevents leakage upward around the screw. Thus two parallel passageways are formed around the tapered end of the screw when the latter is not fully seated, said parallel passageways being of uniform capacity throughout their lengths. By making the taper angle of the screw and hole small and providing the screw with a thread of fine pitch the effective capacity of the passage 40 leading into the receiver chamber 39 can quite easily be adjusted with great nicety.

The servomotor is fitted with stop devices of peculiar construction, one set of devices serving to control the stopping of the advance movement of the motor piston toward the right while the other set of devices controls the stopping of the return movement of the motor piston.

The first set of stop devices comprises a lever 44 supported in the slotted end of block 27 by a pivot pin 45. The lever is formed with an aperture 44a to receive a reduced cylindrical extension 24a of nut 24 and engage a beveled shoulder of the nut. Slidably mounted on the nut extension 24a is an abutment ring 46 which carries a pin 47 movable in the slot 24b of the nut extension. Interposed between the abutment 46 and lever 44 and surrounding the nut extension is a coiled control spring 48, an abutment washer 49 being interposed between the forward end of the spring and the lever, as shown in both Figs. 1 and 2. The spring 48 is made with a working tension greater than the tension of the valve biasing spring 29 and greater also than the excess of the working tension of the relief spring 36 of the transmitter means 30 over the tension of the biasing spring 29. Also slidably mounted on the nut extension 24a is a flanged abutment sleeve 50 which is formed with an inner shoulder to engage the abutment ring 46. Sleeve 50 carries a press fitted pin 51 that extends slidably through slot 24c in the nut extension 24a and maintains the sleeve in operative position. On the outer surface of the sleeve 50 is slidably mounted a contact cap 52 which is formed with slots 52a that engage the ends of pin 51. Interposed between the front end of cap 52 and the front flange of abutment sleeve 50 is an over-travel spring 53. This spring is compressed between parts 50 and 52, before pin 51 is driven in place, to give it a working tension greater than control spring 48. Thus parts 50, 51, 52 and 53 form a yieldable structure slidable on nut extension 24a and capable, through the movable connection afforded by ring 46 and pin 47, of effectively operating the valve structure through control spring 48 and yet yielding to overtravel conditions to be described.

With the motor valve 8 in its neutral or closed position, as shown in Fig. 1, the stop devices are disposed so that the front end of abutment sleeve 50 is spaced slightly away from the adjacent face 27a of block 27, the latter face thus serving to limit forward movement of the sleeve on the nut extension 24a of the valve structure. To cooperate with the described stop devices associated with the valve structure the motor piston rod 6 is provided with a rearward extension 6a which carries a stop arm 54 fitted with an adjustable contact screw 55 to engage the cap 52 when the piston approaches the end of its forward movement.

To provide for the stopping of the return movement of the motor piston additional stop means are provided comprising a depending stop arm 56 adjustably clamped on the front portion of the piston rod 6. This stop arm 56 is fitted with a shouldered bore 57 and screw 58 to retain a stop pin 59 and a second overtravel spring 60. Spring 60 is compressed to an effective tension greater than that of control spring 48. Arm 56 and parts 58, 59 and 60 form a second yieldable structure similar to that of parts 50, 51, 52 and 53.

The stop pin 59 is designed to actuate the abutment lever 44, already described, through a slide 61 which is slotted to receive guide and suspension screws 62 and 63 that slidably support it on the bottom side of the motor

cylinder. One of the slots of slide 61 is located to have its end 61a engage the supporting screw 62 and serve as a stop limiting rearward movement of slide 61. The forward end 61b of slide 61 is arranged to be engaged by stop pin 59 and the rear end 61c is arranged to engage the extended lower end of stop lever 44. Thus as the piston 5 approaches the end of its rearward movement, indicated in Fig. 1, engagement of stop pin 59 with slide end 61b causes rearward swinging of the abutment lever 44 which presses against control spring 48 and causes rearward movement of the motor control valve, the yieldable structure 56, 58, 59 and 60, acting through the movable connecting means 61, 44 and 49, to operate the motor valve through control spring 48.

With the parts of the apparatus in the position shown in Fig. 1 the motor valve is in its neutral or closed position and the motor is at rest. If now the transmitter cam 37 is moved in the direction of the arrow, the cam follower 34a will ride upward on the inclined cam section 37c to the flat-topped section 37b, thus causing movement of arm 34 and causing piston 32 to force fluid from the cylinder 31 through conduit 38 and passages 25a and 40 to the receiver chamber 39. The cam surface 37b is of a height to move the valve 8 toward the left to a fully open position as determined by stop shoulder 27b and give a slight compression to relief spring 36. Thus the fluid pressure in the transmitter system is limited by the tension of spring 36 and the speed of travel of valve 8 is limited by the flow of fluid through restricted passage 40.

With valve 8 open to the left, as the result of the stated movement of cam 37, working fluid passes from inlet duct 13 past valve land 11 and through passage 18 to the left end of cylinder 2. This forces piston 5 to the right while exhaust fluid flows out of the right end of the cylinder through passage 19 past valve land 12 to exhaust duct 15. Piston 5 moves to the right until stop 55 strikes cap 52 and the distinctive stopping action of the present apparatus is brought about, the piston dwelling at the end of its stroke subject to further control action of the cam 37.

Before describing the peculiar stopping action in detail it may be pointed out that it occurs in a small portion of the total stroke of piston 5, say $\frac{1}{8}$ inch out of a total stroke of several feet. Within such small stopping travel of the motor piston occur reactions such as those of a servomotor of the follow-up type, including hunting or chatter, if the reactions are not properly damped. Thus, in the stopping of the motor at the end of the advance movement toward the right the contact screw 55 functions like a follow-up member.

Considering the stopping action of the motor in detail, as the motor piston approaches the end of its forward movement the stop screw 55, as noted above, engages the cap 52. This causes forward movement of the cap, spring 53 and sleeve 50 with resultant compression of the control spring 48 to exert pressure on the motor valve and cause its closing movement. This movement of the parts carries lever 44 and slide 61 to the right as stop pin 59 is not in contact with slide end 61b. The closing movement toward the right of the valve 8 is delayed by the resistance of oil in the receiver chamber 39 caused by the restricted passage 40. This resistance to the valve movement causes compression of spring 48 as the abutment pin 47 moves forward in the slot 24b and this compression of the control spring continues until the front end of abutment sleeve 50 engages the face 27a. At this time valve 8 will not have reached neutral position, so stop screw 55 carries cap 52 further toward the right, compressing spring 53 and holding the sleeve 50 against the stop face 27a. During compression of the spring 53 valve 8 reaches neutral and goes slightly beyond neutral under the pressure of control spring 48, but not to full open position against stop shoulder 25b. The valve has some leakage which prevents shock as it passes neutral position. At this point the left end of slot 24b engages pin 47 and valve 8 can go no farther, being pressed toward the left by transmitter pressure from spring 36. As piston 5 continues toward the right it must force oil through the small port opening of valve 8 and against the inlet pressure of the motor fluid. This develops high cylinder pressure in front of the motor piston, perhaps double the inlet fluid pressure, and dissipates the energy of the motor piston assembly and load yet without noticeable shock.

When the load finally stops, the motor pressure fluid

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is able to re-enter the right end of the cylinder through the small port opening of the motor valve and slowly forces the motor piston 5 to the left, carrying with it stop 55. Spring 53 is then free to extend until the right end of slot 52a strikes pin 51. The valve 8 can then return toward the left to neutral, sleeve 50 moving slightly toward the left away from stop face 27a. Thus the piston 5 and load 7 have been allowed to travel at high speed past the desired position, been decelerated gently and then returned slowly to the desired position as determined by the setting of stop 55. The deceleration is controlled by the slow speed of valve motion as determined by restricted passage 40. The slow return of the piston 5 is accomplished by the slight reverse opening of the valve limited by the position of sleeve 50 against surface 27a.

In practice the load 7 appears to bounce once but not twice. A heavier load bounces or overtravels further but returns to the same accurate position without hunting. Thus the apparatus is able to stop and locate work pieces of widely varying weight without special adjustment.

During the dwell of the motor piston at the forward end of its stroke some machine operation may be performed on a work piece mounted on machine part 7. Meanwhile cam 37 advances, and as follower 34a rides from level cam surface 37b down surface 37d to surface 37a the transmitter pressure is released and valve 8 is permitted to move fully open to the right against stop shoulder 25b under the pressure of biasing spring 29. In this movement of the valve, abutment ring 46 moves toward the right from the shoulder in abutment sleeve 50 because travel of this sleeve is limited by stop surface 27a.

Piston 5 now travels toward the left at full speed until stop pin 59 strikes the end 61b of slide 61. This action moves slide 61 rearward until its stop surface 61a engages screw 62. This movement of slide 61 moves abutment lever 44 to the left in relation to the shoulder of valve nut 24 to compress spring 48 enough to overcome the biasing spring 29 and effect leftward movement of the valve 8 to and slightly beyond neutral position. The parts are designed so that the engagement of slide 61 with screw 62 occurs when the valve 8 is slightly to the left of its neutral position, this stop action corresponding to that caused by the stop surface 27a at the end of the advance movement of the motor piston. When movement of slide 61 is stopped by engagement with screw 62 the overtravel spring 60 yields (in a manner corresponding to the compression of spring 53 during the stopping of the forward movement of the motor piston) and permits the motor piston and load to come to rest gradually and smoothly due to the dash pot action which forces working fluid from the motor cylinder space behind the piston through the small port opening of valve 8 against the inlet pressure of the motor fluid as previously described in connection with the stopping of the forward movement of the motor piston, and, as in the latter case, the motor piston is returned by the pressure of the inlet fluid to its predetermined position corresponding to the setting of the stop arm 56 on piston rod 6. This return movement permits the spring 48 to re-expand and restore valve 8 to its fully closed position.

In the stopping of the return movement of the motor piston the described movement of the motor valve 8 toward the left is effected gradually by the action of the restrictor passage 40 which insures a gradual entry of working fluid into the receiver chamber 39 under the suction effect of the valve movement toward the left. Thus it will be seen that the action of the restrictor passage 40 between the conduit 38 and the receiver chamber effectively damps speed of valve motion in both directions.

The required relative strengths of springs 36, 29, 48 and 53 were indicated in describing the apparatus, but from the above description of the operation of the apparatus it will more readily be understood that the overtravel spring 53 of the valve assembly must have enough tension, combined with tension of return spring 29, to overcome the tension of spring 36, bearing in mind that the transmitter may be under full pressure when stopping motor movement to the right. When stopping motor movement to the left, control spring 48 must have more tension than biasing spring 29 in order to move valve

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8 to neutral. In a particular design of the apparatus, spring 29 has a tension of 5 pounds, this being needed to force control fluid back through conduit 38 to permit a motor piston speed of 8" per second. Control spring 48 then needs a tension of 7 pounds to overcome the tension of spring 29 plus valve friction. The two tensions combined (12 pounds) must overcome spring 36 which may have an effective tension of ten pounds, or double the tension of spring 29. This allows a five pound pressure to force control fluid forward through conduit 38.

With an effective area of diaphragm 21 of $\frac{1}{8}$ of a square inch, the maximum force of the vacuum in the receiver chamber 39 is five pounds. Control spring 48 at seven pounds tension has only a two pound excess over the five pound tension of spring 29 so that the five pound vacuum is sufficient to compress control spring 48 for stopping motor movement to the left.

It will be understood that the disclosure herein of a specific form of apparatus for purposes of explanation is not intended to indicate limitations on the application of the present improvements. For example, it will be apparent that the improvements may be applied in motor applications such as are illustrated in Fig. 1 of my previously-mentioned Patent No. 2,580,686, in which the yieldable stop cap 52 of my improved apparatus may be arranged to engage or be engaged by an unyielding stop member, as herein disclosed, or to engage or be engaged by a template and function as a tracer.

Again it will be apparent that the yielding action of the transmitter spring 36, in so far as its cooperation with restrictor 40 is concerned, can be introduced at any point between the cam follower and the restrictor 40. The arrangement of the spring 36 in conjunction with transmitter lever 34 as herein disclosed, has been preferred since it permits the additional useful functioning of the spring for purposes disclosed in my previously-mentioned patents.

Also it will be apparent that the type of motor shown herein is not part of the invention and that this stop mechanism can be readily applied to other well known types of fluid motors.

I do not claim herein transmitter-controlled servomotor apparatus in which the fluid conduit means connecting the transmitter and a receiver chamber and comprising a series-connected unrestricted passageway and an adjustable restricted passageway are used either with or without automatic means for stopping the motor and without cooperating means for accurately positioning the movable power element of the motor, since such apparatus constitutes the subject matter of my earlier filed application Serial No. 382,960, filed September 29, 1953.

What is claimed is:

1. Transmitter-controlled hydraulic servomotor apparatus comprising a hydraulic motor having relatively movable power elements; a movably mounted valve structure for controlling admission and exhaust of working fluid to and from the working chamber of the motor; means for actuating the valve comprising yieldable biasing means for moving it in one direction, a receiver chamber, pressure-responsive means connected to the valve and exposed to the pressure of fluid in the receiver chamber to move the valve in the opposite direction, a fluid transmitter, means for actuating the transmitter, fluid conduit means connecting the transmitter and receiver chambers comprising an unrestricted passageway connected at one end to the transmitter chamber and a restricted passageway connected with the other end of the unrestricted passageway and with the receiver chamber, adjustable means for varying fluid flow through the restricted passageway to and from the receiver chamber, and relief means operatively connected with the transmitter and the unrestricted passageway constructed to yield only under a predetermined transmitter pressure greater than the force of the valve biasing means; and control means for stopping the motor comprising a control spring arranged to exert effective pressure on the valve structure parallel to the path of its movement and having a working tension greater than the force of the valve biasing means and greater than the excess of the relief means tension over the valve biasing force, a yieldable overtravel structure having a greater working tension than the control spring, movable connecting means interposed between the control spring and one end of the overtravel structure, means for definitely limiting the

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movement of the said connecting means in a direction opposing the tension of the control spring, operative connecting means between the other end of the overtravel structure and the movable power element of the motor to apply tension-increasing force to the control spring and effect reversal movement of the valve through and beyond closed position against the tension of the transmitter relief means, whereby a stopping resistance to overtravel of the moving motor member and the subsequent slow return of the said motor member to a predetermined position and of the valve to its closed position are effected.

2. Transmitter-controlled hydraulic servomotor apparatus as claimed in claim 1 in which the control means for stopping the motor is constructed to stop both the advance and the return movements of its movable power element and comprises a control spring for exerting pressure on the motor valve in either direction of its movement, said spring having a working tension greater than the force of the valve biasing means and greater than the excess of the relief means tension over the valve biasing force, first and second movable abutments respectively interposed between the valve structure and the two ends of the control spring to transmit pressure from the spring to the said structure alternatively in opposite directions, an overtravel spring having a greater working tension than the control spring, movable connecting means interposed between the first movable abutment of the control spring and one end of the overtravel spring, means for definitely limiting the movement of the said connecting means in a direction opposing the tension of the control spring, a movable abutment structure engaging the other

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end of the overtravel spring, a stop structure operatively connected with the movable power element of the motor and arranged to engage the said overtravel structure in the forward motor movement to apply tension-increasing force to the control spring and effect reversal movement of the valve through and somewhat beyond closed position against the resistance of the restricted passageway and the tension of the transmitter relief means, a second stop structure operatively connected with the movable power element of the motor and means comprising a second overtravel spring having a greater working tension than the control spring arranged to transmit return motor movement of the second stop structure to the second movable abutment of the control spring to effect reversal movement of the valve through and somewhat beyond closed position against the resistance of the restricted passageway, and means for definitely limiting the movement transmitted to the said second abutment from the second overtravel structure, whereby the respective stop devices act through the control spring to stop the forward and reverse movements, respectively, of the motor.

3. Apparatus as claimed in claim 1 in which the restricted passageway is formed with a tapered hole transversely intersecting the passageway and of a larger diameter than the passageway and in which the adjustable means for varying fluid flow through the restrictor passageway comprises a screw having one end tapered to fit and cooperate with the wall of the tapered hole.

No references cited.