June 9, 1964 J. L. GRATZMULLER 3,136,226

CONTROL SYSTEM FOR HYDRAULIC ACTUATORS

Filed March 7, 1960 3 Sheets-Sheet 1

FIG.1

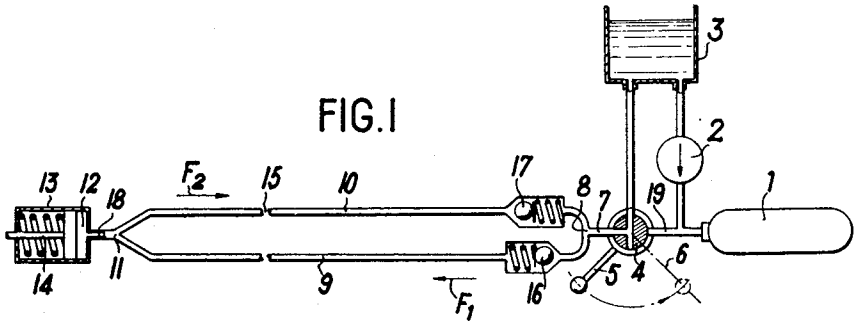


FIG.2

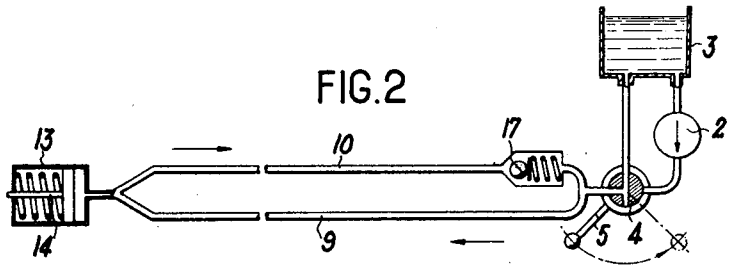


FIG.3

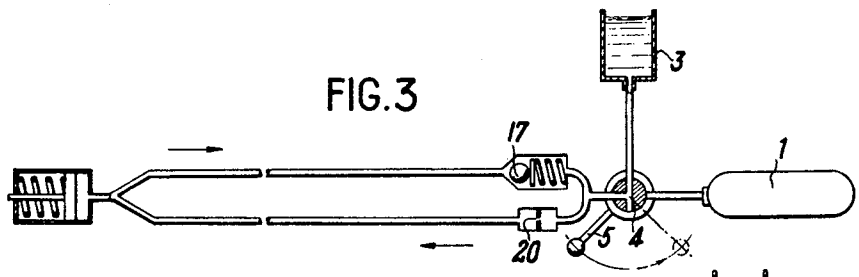
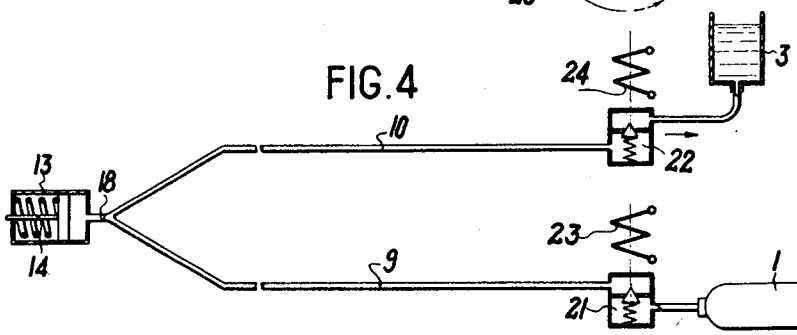


FIG.4



June 9, 1964 J. L. GRATZMULLER 3,136,226

CONTROL SYSTEM FOR HYDRAULIC ACTUATORS

Filed March 7, 1960 3 Sheets-Sheet 2

FIG.5

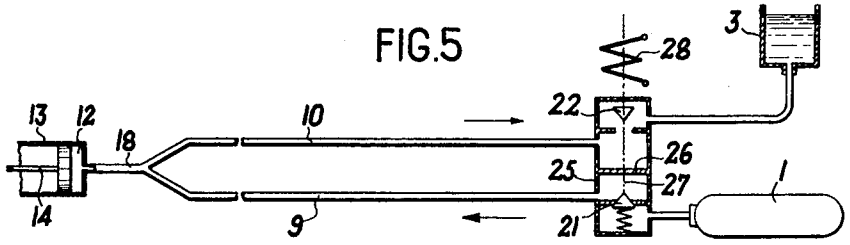


FIG.6

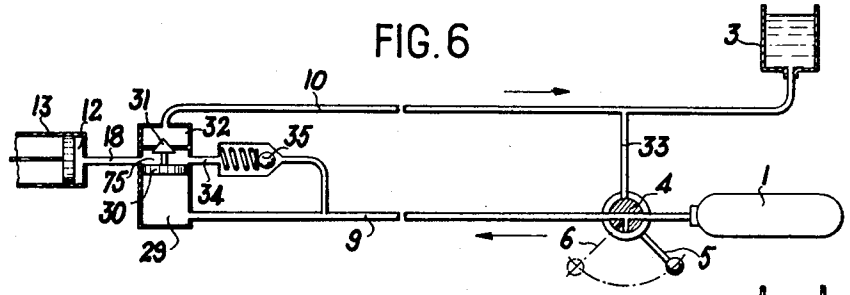


FIG.7

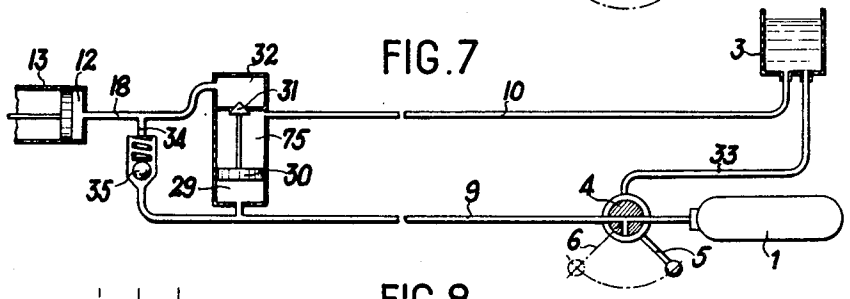
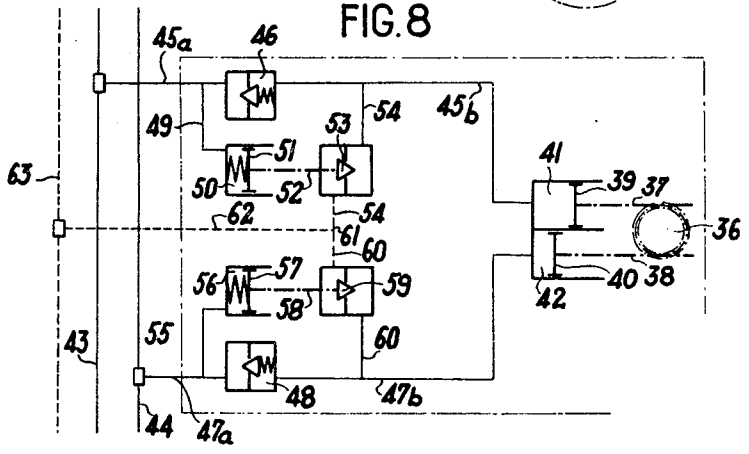


FIG.8



June 9, 1964 J. L. GRATZMULLER 3,136,226

CONTROL SYSTEM FOR HYDRAULIC ACTUATORS

Filed March 7, 1960 3 Sheets-Sheet 3

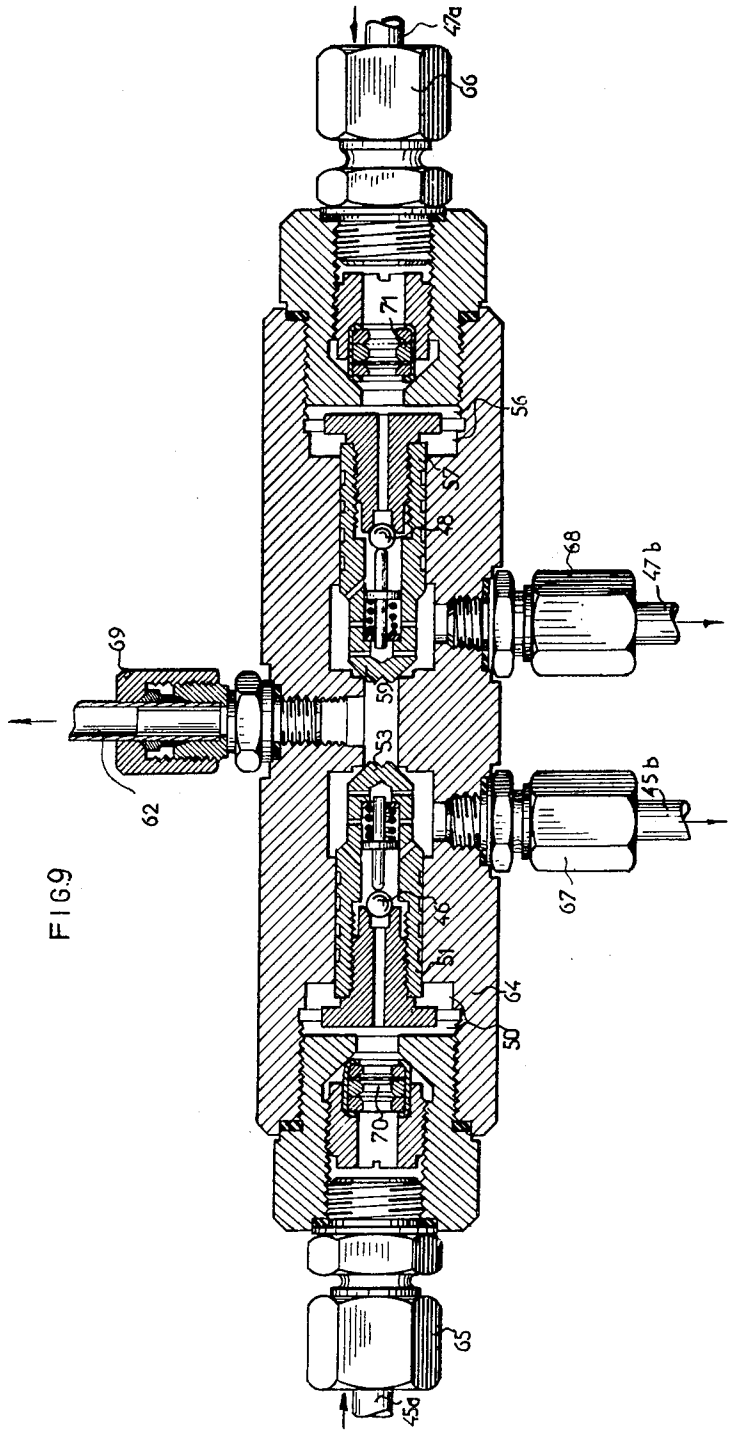


FIG 9

United States Patent Office

3,136,226
Patented June 9, 1964

3,136,226

CONTROL SYSTEM FOR HYDRAULIC ACTUATORS

Jean Louis Gratzmuller, 66 Blvd. Maurice Barrès, Neuilly-sur-Seine, France

Filed Mar. 7, 1960, Ser. No. 13,380
Claims priority, application France Mar. 6, 1959
5 Claims. (Cl. 91—442)

This invention relates to the control of hydraulic actuators, more particularly of a single-acting hydraulic actuator, having an active stroke and a return stroke, fed with hydraulic liquid from a high-pressure source and exhausting into a low-pressure receiver; or of a pair of single-acting actuators so mechanically interconnected that the active stroke of one synchronises with the return stroke of the other, or of a double-acting actuator functionally equivalent to such mechanically interconnected pair of single-acting actuators.

The invention is particularly, but not exclusively, applicable to the control of actuators operating a section switch in an electrical transmission line, for which absolutely positive action in opening and closing the switch is essential.

The invention is mainly concerned with the problem of purging air trapped in the hydraulic circuits, the presence of such trapped air being fatal to positive action of the actuator(s).

Hitherto, various means for purging the circuits of trapped air have been adopted or proposed, of which many require the provision of auxiliary equipment, e.g. suction pumps, and/or a relatively complicated setting-up procedure, manually controlled. Another conventional expedient is to design the geometrical lay-out of the circuit(s) so that trapped air naturally finds its way to points from which it can easily be bled-off. This expedient imposes severe limitations on the design of circuits and to a great extent deprives the hydraulic transmission system of one of its main advantages (shared by electrical transmission systems but not by mechanical transmissions) namely adaptability to any required geometrical lay-out.

The present invention aims to provide fully automatic means for purging trapped air from the hydraulic circuit(s) in the course of a certain number of initial cycles, each comprising a "feed" phase and an "exhaust" phase; and thereafter, during the course of normal operation, for continuously and promptly purging the circuit(s) of any air that may subsequently enter. The initial cycles referred to may, if necessary, be of the nature of "dummy runs"; thus, if the actuator(s) operate a section switch, the initial cycles may be carried out with the electrical transmission line "dead."

An object of the invention is a system of ducting connected to the actuator to be served and selectively connectible either to the high pressure source or to the low pressure receiver, such duct system comprising two parallel branches, together with means ensuring that during the "feed" phase substantially all the liquid required to effect the active stroke of the actuator is transferred thereto via one of such branches (hereafter referred to as the "first" branch) whereas during the "exhaust" phase a substantial part (of the order of half or more) of the

liquid expelled from the actuator is transferred to the receiver via the other of such branches (hereafter referred to as the "second" branch).

This arrangement ensures that the liquid expelled through the second branch entrains a certain amount of the air previously trapped in the working chamber of the actuator and adjacent regions of the ducting.

This effect is due to the phenomenon that when a liquid in contact with air in a confined space undergoes a considerable rise of pressure, however rapid, some of the air becomes dissolved in the liquid; and when the liquid containing dissolved air undergoes a rapid fall of pressure, this air comes out of solution and becomes dispersed in the liquid in particles of a colloidal size, and that the release from a liquid of air so colloidally dispersed takes place very slowly.

Consequently, when liquid under pressure containing entrapped air is injected into the working chamber of the actuator, some of this air is dissolved in the liquid; and when this liquid is expelled at a lower pressure in the exhaust phase it will entrain the previously dissolved air in colloidal dispersion.

Now, if feeding and exhausting were to take place, as in conventional practice, through the same duct, and if, as is likely, the length of that duct were such that its volumetric capacity considerably exceeded that of the working chamber of the actuator, the "dose" of liquid charged with colloidally dispersed air would never reach the receiver, but would remain in the duct; and at the next feed phase would be driven back into the working chamber taking the colloidally dispersed air with it, so that no purging of trapped air would take place.

However, by diverting part at least of the expelled liquid containing colloidally dispersed air into a second duct, which takes no part in the feed phase, this part of the expelled liquid is removed from the duct system into the receiver, where it has time to rid itself of the dispersed air. It follows that by successive repetitions of the alternating feed and exhaust phases all the air trapped in the system will ultimately be evacuated into the receiver and that any air that may subsequently find its way into the system, e.g. through imperfectly air-tight joints, will be evacuable in the same way.

The control system of this invention is susceptible of a number of specific constructional embodiments as hereinafter described.

The invention further includes a complete hydraulic installation for operating a section-switch in an electrical transmission line or analogous apparatus requiring to be positively displaced through a limited stroke in alternate directions, embodying means as described above for purging the hydraulic circuits of trapped air.

The invention also includes a sub-combination consisting of a unitary valve assembly for incorporation in a hydraulic installation of the kind referred to in the preceding paragraph, a non-limitative example of such sub-combination being described with reference to FIGURE 9 of the accompanying drawings.

In what follows, constructional embodiments of the invention are described, by way of example only, with reference to the accompanying drawings, it being understood that the following description is not limitative of the scope of the invention, which is defined in the hereto appended claims.

In the drawings:

FIGURE 1 illustrates schematically a hydraulic control device with automatic purgation of air compresing two non-return valves;

FIGURE 2 is a similar view of a similar control device having only one non-return valve;

FIGURE 3 illustrates a modification of the device of FIGURE 2, in which the feed branch has a flow-restrictor;

FIGURE 4 illustrates another modification in which the distributor is constituted by two separate electrovalves;

FIGURE 5 illustrates a constructional modification of the arrangement of FIGURE 4, in which the two valves are housed in a single chambered body;

FIGURE 6 illustrates schematically a constructional embodiment of the invention, in which the purgation device is remotely controlled;

FIGURE 7 illustrates a modification of the device of FIGURE 6 having a low-pressure valve;

FIGURE 8 is a diagram illustrating a hydraulic control system of a section switch in an electric transmission line; and

FIGURE 9 is an elevation partly in longitudinal section of a constructional arrangement having remotely controlled purgation devices (as in FIGURE 7) and a single exhaust and purging connection, mounted in a single block to form a self-contained unit.

In the embodiment of the invention illustrated in FIGURE 1, the high-pressure hydraulic source is an oleo-pneumatic accumulator **1**, in which pressure is maintained by a pump **2** drawing liquid from the low-pressure receiver **3** previously referred to.

The selector (which is connected to the accumulator **1** by a duct **19**) is constituted by a two-position three-way cock **4**, whose operating handle **5** is shown in full line in the exhaust and purging position, its feed position being indicated at **6** in chain-dotted line. A duct **7** which serves both for feed and exhaust (purge) extending from cock **4** is branched at **8** to form a feed line **9** and an exhaust line **10** together forming the doubled conduit, which is characteristic of the invention. Lines **9** and **10** are re-connected at **11** and are continued by a duct **18** which takes flow in both directions, to and from the working chamber **12** of a single acting jack **13**, whose piston is indicated at **14** and which constitutes the actuator previously mentioned. Lines **9** and **10** may be of indefinite length, to illustrate which a "cut" is shown at **15**. Line **9** contains a non-return valve **16** which allows flow to take place only in the direction indicated by arrow F_1, and line **10** contains a non-return valve **17** which only allows flow in the opposite direction indicated by arrow F_2.

This control device operates as follows: Initially, with the selector handle in the "purge" position as shown, all the ducts and lines **7**, **9**, **10**, **18** are full of air, and since the receiver **3** is so placed that the head of liquid above the selector cock **4** is not very great no appreciable quantity of liquid can enter the system from the receiver through duct **7**.

At the same time the accumulator **1** is at the working pressure of the installation (as maintained by the action of pump **2**).

On moving the handle **5** to the "feed" position **6**, accumulator **1** is put into communication, via duct **19**, selector **4**, duct **7**, non-return valve **16**, feed line **9** and duct **18** with the chamber **12** of jack **13**, the non-return valve **16** allowing liquid to pass freely through the channel thus constituted. Some high pressure liquid also enters the line **10** at **8**, but cannot get past the non-return valve **17**.

The high pressure liquid entering the chamber **12** effects the active stroke of piston **14** and at the same time enters the line **10** and compresses the air in it against the non-return valve **17**, however, will not open because of the back-pressure exerted on it as long as the selector cock is in the feed position. Air trapped in the dead space of chamber **12** and duct **18** becomes partly dissolved in the high pressure liquid entering this space.

On moving the handle **5** to the "purge" position, communication between the accumulator **1** and the jack **13** is shut-off and jack **13** is put into communication with the receiver **3**. Pressure in chamber **12** falls and air dissolved in the liquid in this chamber comes out of solution and forms a colloidal dispersion. The drop in pressure allows the piston **14** to be returned to its initial position by return means, shown as a spring in FIGS. 1–4, driving the liquid contents of chamber **12** into the duct **18**, from which it cannot pass into line **9** because of the obstruction offered at the far end by the non-return valve **16**. Consequently, the liquid expelled from chamber **12** and duct **18** is forced into line **10**. If the return stroke of the piston is rapid enough the whole column of liquid contained in the exhaust circuit (**10** etc.) will, by reason of its inertia, be expelled through the non-return valve **17** towards the receiver **3**, becoming separated from the piston **14** and causing a partial void in chamber **12**. This column of liquid will also drive in front of it the air previously compressed between it and the non-return valve **17**. This then gives rise to a back-flow of liquid from the receiver **3** towards the jack **13**, via the feed line **9**, since the non-return valve **17** prevents back-flow through the line **10**. This back-flow of low-pressure liquid re-fills the void previously formed in chamber **12**. In this way, due to the inertia of the liquid and the action of the non-return valve **17**, the return stroke of the piston would, if rapid enough, causes some of the colloidally dispersed air to be positively expelled from the chamber **12** into the receiver **3**, even if the volume of the duct **18** were somewhat greater than that of chamber **12**; and if duct **18** has a decidedly smaller volume than chamber **12** (as shown in FIGURE 1) positive expulsion, at each return stroke of piston **14**, of part of the air trapped in chamber **12** will be achieved, whatever may be the speed at which the piston moves during the return stroke.

Any suitable or conventional return means such as a weight, air cushion, may of course be used in place of the spring of FIGURES 1–4.

The sequence of events described above is repeated at each complete operating cycle of jack **13**, comprising a feed stroke and an exhaust stroke, with the result that air initially trapped in chamber **12** is progressively eliminated by successive stages of solution, colloidal dispersion in the liquid and transference of successive "doses" of liquid into the receiver **3**. Once the liquid reaches the receiver it stays there for long enough to become free of entrained air before being returned into circuit by the pump **2**.

The embodiment of FIGURE 2 differs from that of FIGURE 1 only by omission of the non-return valve **16** and its operation is substantially the same, except that during the exhaust stroke liquid containing colloidally dispersed air is expelled into both lines **9** and **10** in substantially equal proportions. That part of the liquid expelled via line **10** is transferred to the receiver **3** as in the embodiment of FIGURE 1, but if the volumetric capacity of line **9** is greater than that of the working chamber **12**, the "dose" of liquid containing dispersed air will not reach the selector cock and in the next cycle, when the selector cock is put in the "feed" position, this dose of liquid will be returned to the working chamber **12**. However, at each cycle some of the entrained air is eliminated through line **10**, but evidently with the embodiment of FIGURE 2 more successive cycles of feed and exhaust are required to effect complete purgation of the air initially trapped in the hydraulic circuits than in the case with the embodiment of FIGURE 1.

The embodiment of FIGURE 3 differs from that of FIGURE 2 only by the provision of a flow-restrictor **20**

in the feed line 9, the effect of which is that, in the exhaust stroke of the jack, the greater part of the liquid containing colloidally dispersed air is evacuated via the exhaust line 10. The same result could also be obtained by giving the feed line 9 a smaller cross-section than the exhaust line 10.

In the embodiment of FIGURE 4, the selector is constituted by two electro-hydraulic valves 21, 22, which also replace the non-return valves 16, 17 of FIGURE 1. The solenoids 23, 24, which, when excited, unseat the valves 21, 22 respectively against the effort of springs, are controlled by switch means (not illustrated) so that when one is excited the other is not and conversely. Thus, when valve 21 is opened to put the accumulator 1 into communication with the jack 13 via the feed line 9, valve 22 is closed, thus obstructing the exhaust line 10 in the same way as does the non-return valve 17 of FIGURE 1. Similarly, when valve 22 is opened for exhausting the jack 13 and for purging the air from the exhausted liquid, valve 21 is closed and obstructs the feed line 9 in the same way as does the non-return valve 16 of FIGURE 1. The operational sequence is therefore strictly comparable with that of the embodiment of FIGURE 1.

The arrangement of FIGURE 5 differs from that of FIGURE 4 only in this, that the valves 21, 22 are disposed in a common housing 25 sub-divided into two compartments by a partition 26, and that the valve members are interconnected mechanically as by a rod 27 which passes through the partition and are operated by a single solenoid 28, with spring-return means. Excitation of the solenoid unseats valve 21 and seats valve 22 and when the solenoid is not excited the spring seats valve 21 and unseats valve 22.

The embodiment of FIGURE 6 comprises, as before, the accumulator 1, receiver 3, selector cock 4, feed line 9, exhaust line 10 and the common feed and exhaust duct 18 connected to the working chamber 12 of the jack 13. In this embodiment the selector cock 4, which is connected to line 10 via an auxiliary duct 33, is remote from the "purgation" device 29—34 and 75 hereinafter described. In this figure the handle 5 of the selector cock is shown in full line in the "feed" position and in chain-dotted line, at 6, in the exhaust position.

The "purgation" device comprises a cylinder subdivided into three chambers 29, 75 and 32 by a floating piston 30 separating chamber 29 from chamber 75 and a fixed partition separating chamber 75 from chamber 32 and having a central opening forming the seating on which a valve 31 rigidly connected to piston 30 is seatable from below (as seen in the figure). Chamber 29 communicates freely with the feed line 9 and chamber 32 communicates freely with the exhaust line 10; and chamber 75 communicates freely with the duct 18 and also communicates with the line 9, via a by-pass 34 containing a non-return valve 35, which allows flow only from line 9 to chamber 75.

This arrangement operates as follows: With the selector cock in the feed position, as shown, high pressure liquid is fed, via line 9, non-return valve 35, by-pass 34, chamber 75 and duct 18 to the jack 13. At the same time high-pressure is maintained in chamber 29, so that the pressures on either face of piston 30 are equalised while valve 31 is subjected to the high pressure in chamber 75 which is opposed by the low pressure subsisting in the receiver 3 acting on the opposite face of valve 31, so that the latter is held on its seat.

As in the previous examples, it follows that air trapped in the working chamber 12 of the jack 13, in the duct 18, in the chamber 75 and in the by-pass 34 becomes dissolved, at least partially, in the high-pressure liquid, while, concurrently, the active stroke of the jack 13 is accomplished.

When the selector cock is thrown over to the exhaust position, line 9 is cut-off from the accumulator 1 and put into communication, via duct 33, with the receiver 3. Consequently, the pressure in chamber 29 falls and allows the pressure already established in chamber 12, duct 18 and chamber 75 to move the floating piston 30 downwards (as seen in the figure) and unseat the valve 31, at the same time expelling some of the liquid in chamber 29, through line 9 and duct 33 into the receiver 3. Unseating of valve 31 relieves the pressure in chamber 12, duct 18, chamber 75 and by-pass 34, causing the air dissolved in the column of liquid contained in these spaces to come out of solution and be colloidally dispersed in the liquid, which is expelled into the exhaust line 10, while the non-return valve 35 prevents the expelled liquid from entering the feed line 9 in the same way as does the non-return valve 16 of FIGURE 1.

It may also be noted that the pressure subsisting in the chamber 12 keeps the valve 31 seated as long as the chamber 29 is subjected to the high (service) pressure.

The embodiment of FIGURE 7 differs from that of FIGURE 6 in the following particulars:

The duct 18 is connected to chamber 32, the exhaust line 10 is connected to chamber 75 and by-pass 34 (with non-return valve 35) connects chamber 32 to the feed line 9.

This embodiment operates similarly to that of FIGURE 6, except that the pressure subsisting in chamber 12 holds valve 31 unseated, except when the high (service) pressure is transmitted to chamber 29.

In the embodiments of FIGURES 6 and 7, the valve arrangement positively prevents any liquid under high (service) pressure from entering the exhaust line 10, for which a tube made of material of relatively low mechanical strength may be used, with consequent saving of first cost. Moreover, this tube may be common to several "actuators," provided they are not required to operate simultaneously.

In a modification of the embodiment of FIGURE 6 or FIGURE 7 which is not illustrated, the exhaust and purging valve 31 may deliver into a local, intermediate receiver at atmospheric pressure, disposed at a slightly higher level than the main receiver 3 and connected with it by the exhaust line 10. The jack 13 is then exhausted as rapidly as may be required into the intermediate receiver, whence the liquid flows slowly into the main receiver 3.

The hydraulic control system of a section switch diagrammatically illustrated in FIGURE 8 comprises two purging devices with a single, common exhaust line.

The section switch, which is not itself illustrated, is operated positively in both senses, i.e. for opening and closing, by two single-acting hydraulic actuators (which could be replaced by a single, double-acting actuator) so coupled that the active stroke of one of them effects the return stroke of the other. In the form illustrated, this arrangement takes the form of two, identically similar, single-acting hydraulic jacks 41, 42, whose respective pistons 39, 40 are rigidly connected to toothed racks 37, 38 engaging a toothed wheel 36 which actuates the section switch. The active stroke of one such jack, say 41, effects the closing of the switch, while the active stroke of the other jack 42 effects the opening of the switch.

The system includes two feed lines 43, 44, corresponding to the line 9 of FIGURE 7 and selectively connectible (as in FIGURE 7) by means of a remote selector cock assembly (not illustrated) to a high-pressure hydraulic source, such as accumulator 1 of FIGURE 7, or to a low-pressure receiver, such as the receiver 3 of FIGURE 7, in such a way that, when line 43 is connected to the high pressure source, line 44 is connected to the receiver and conversely. The system also includes a single exhaust and purge line 63, corresponding to line 10 of FIGURE 7, permanently communicating with the receiver.

The system further includes two purgation assemblies of the type illustrated in FIGURE 7 and identified therein by the reference characters 18, 29–35 and 75, and respectively associated with jack 41 and line 43 and with

jack 42 and line 44, both such assemblies being connected to the common exhaust and purge line 63. Since these two purgation assemblies are identically similar, it will suffice to describe one of them, the corresponding reference characters for the other such assembly being inserted in brackets.

From jack 41 (42) extends a duct 45*b* (47*b*) corresponding to duct 18 of FIGURE 7, having a branch 45*a* (47*a*) connected to line 43 (44) and containing a non-return valve 46 (48). This corresponds to the assemblage 34, 35 of FIGURE 7. Another branch 54 (60) of duct 45*b* (47*b*) containing a valve 53 (59) is connected at 61 to a duct 62, common to both purgation assemblies and communicating with the common exhaust and purging line 63. Valve 53 (59) is rigidly connected by a member 52 (58) with a piston 51 (57) movable in a cylinder 50 (56) and loaded by a spring in the direction to seat the valve 53 (59) the closed end of the cylinder 50 (56) being connected by a duct 49 (55) with the branch duct 45*a* (47*a*). The assemblage 50–53 (56–59) corresponds with the assemblage 29, 30, 75, 31, 32 of FIGURE 7.

It is to be understood that the volumetric capacities of the lines 45*b*, 47*b* are such that the quantity of pressure liquid required to fill either of them is less than that expelled from the working chamber 41 or 42.

It will be evident from the foregoing description that the elements enclosed within the double-dotted rectangle of FIGURE 8 are exactly analogous to a duplication of the elements shown in FIGURE 7 to the left of "break" line (as seen in the figure) and that they operate in exactly the same way, the operative cycles of the duplicated sets of elements (of FIGURE 8) being "anti-phased," in the sense that the "feeding" phase of the one coincides with the "exhaust and purging" phase of the other, due to the arrangement of the (non-illustrated) selector cock assembly previously described.

FIGURE 9 illustrates a unitary constructional embodiment of duplicated "purgation" assemblies, as diagrammatically illustrated in FIGURE 8, it being understood that this constructional embodiment is not limited in its application to the control of section switches, but is generally applicable to any hydraulic control system required to perform analogous duty. In describing FIGURE 9, elements having strict analogues in FIGURES 8 are identified by the same reference characters.

The embodiment of FIGURE 9 comprises a single, hollow body 64 having five external connections, viz. at each end connections 65, 66 for the branch ducts 45*a*, 47*a*, side connections 67, 68 for the ducts 45*b*, 47*b* and (on the opposite side) a single connection 69 for the common exhaust and purge line 62.

Connection 69 communicates freely with the central bore of the body 64 at its mid point, on either side of which the central bore is enlarged to form chambers communicating freely with the connections 67 and 68 respectively and providing seatings for the valves 53, 59, which when unseated provide communication between the lines 45*b*, 47*b* respectively and the line 62. Valves 53, 59 are respectively unitary with pistons 51, 57, whose cylinders 50, 56 are formed by further enlargements of the central bore of the body 64, which communicate with the connections 65, 66 respectively.

The pistons 51, 57 are hollow and enclose the non-return valves 46, 48, consisting of spring-loaded balls, the interior of the pistons downstream of the balls being vented to the chambers communicating with the external connections 67, 68; and the ball-seatings being formed on the ends of central passages communicating with the interior of cylinders 50, 56.

Comparison of the structural arrangement of FIGURE 9 with that diagrammatically illustrated in FIGURE 8 will show that they are strictly analogous, except that in the arrangement of FIGURE 9 the pistons 51, 57 and valves 53, 59 are not spring-loaded, which is not really essential (see also FIGURE 7).

In addition, the constructional embodiment of FIGURE 9 includes, in the passages connecting cylinders 50, 56 with the external connections 65, 66 respectively, oil filters 70, 71 in the form of stacked, pierced washers.

The embodiment of FIGURE 9 is designed for ease in machining, since nearly all the machining operations required are by way of coaxially boring from each end of the assembly.

Having thus described the invention, what is claimed as new and desired to be secured by Letters Patent is:

1. Hydraulic apparatus comprising in combination a hydraulic actuator having an active stroke and a return stroke and comprising a working chamber of variable volume, a high-pressure source of hydraulic liquid, a low-pressure receiver of liquid exhausted from the actuator, a two-position selector cock for selectively connecting the working chamber of the actuator alternately to the high-pressure source and to the receiver, ducting connecting said selector cock with said working chamber, said ducting comprising for the smaller part of its length a combined feed and exhaust pipe connected to said working chamber and of such volumetric capacity that the quantity of hydraulic liquid filling said pipe is smaller than the quantity of hydraulic liquid expelled from the working chamber during the return stroke of the actuator, and for the greater part of its length two parallel branches, namely a first and a second branch, said second branch being connected directly to said receiver and said first branch being selectively connectible through said selector cock to said source and to said receiver alternatively, a cylinder communicating with said first branch, a piston in said cylinder, a valve operative between said second branch and said working chamber, said valve being so actuated by said piston as to be urged to closed position by the pressure in said cylinder and to open position by the pressure in said second branch, a by-pass connecting said working chamber with said cylinder and first branch and a non-return valve in said by-pass preventing flow from said working chamber towards said cylinder and first branch.

2. Hydraulic apparatus comprising, in combination, a hydraulic actuator having an active stroke and a return stroke and comprising a working chamber of variable volume, a source of liquid under pressure, a tank, a pressure liquid supply line connected to said working chamber, a two-position selector valve for selectively connecting said supply line to said source or to said tank, a return line connected to said tank and communicating with said supply line at a point thereof near said working chamber, a portion of said supply line extending between said point and said working chamber constituting a combined supply and exhaust conduit of such volumetric capacity that the quantity of pressure liquid filling said portion is smaller than the quantity of pressure liquid expelled from said working chamber during said return stroke of the actuator, valve means for controlling said communication between the supply line and return line, and means responsive to the fluid pressure in said supply line for actuating said valve means so as to close said communication when the supply line is connected to said source and to open said communication when the supply line is connected to said tank, and a non-return valve in said supply line preventing the pressure liquid expelled from said working chamber through said combined supply and exhaust conduit to flow to said pressure responsive means and to said selector valve.

3. Hydraulic apparatus according to claim 2, in which said pressure responsive means comprise a cylinder having a fixed partition and a piston therein, an opening in said partition, said partition and piston dividing said cylinder into three cylinder spaces, and in which said valve means comprise a movable valve member connected to said piston and cooperating with a valve seat formed by said opening in said partition, said supply line having a

branch connected to said cylinder to conduct pressure liquid from said source to the face of said piston remote from said partition, the pressure liquid expelled from said working chamber through said combined supply and exhaust conduit being conducted to the cylinder space at one side of said partition, and said return line being connected to the cylinder space at the other side of said partition.

4. Hydraulic apparatus acording to claim 3, in which the cylinder space to which said combined supply and exhaust conduit is connected, is located between said piston and said partition.

5. Hydraulic apparatus according to claim 3, in which cylinder space to which said return line is connected is located between said piston and said partition.

References Cited in the file of this patent

UNITED STATES PATENTS

2,933,069 Gratzmuller ---------- Apr. 19, 1960