Sept. 4, 1956 F. F. OFFNER 2,761,645

SERVO SYSTEM

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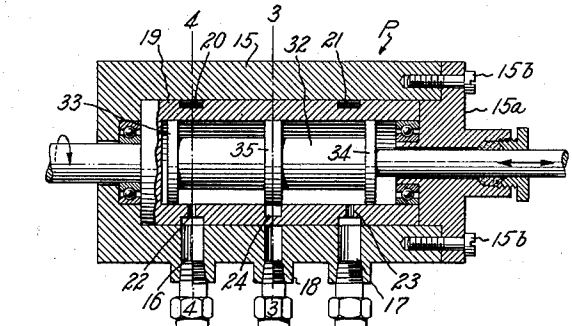
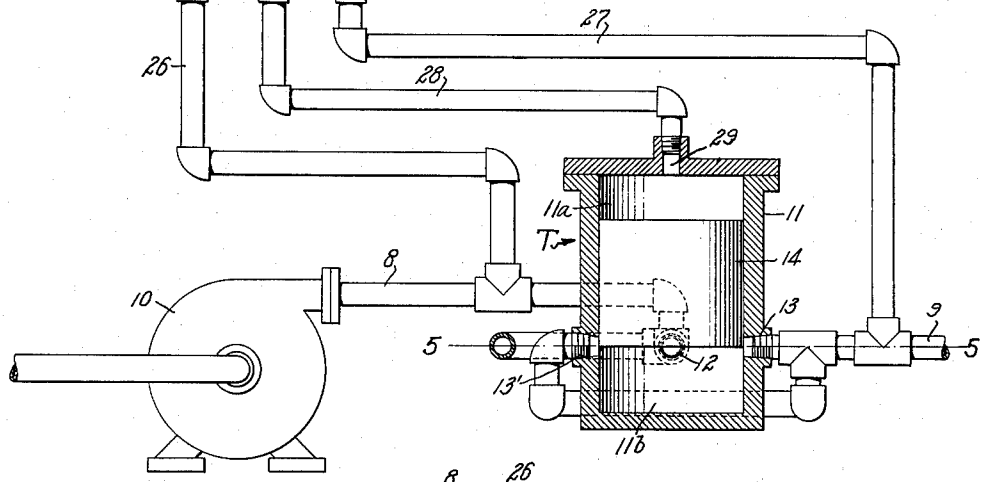


Fig. 1.



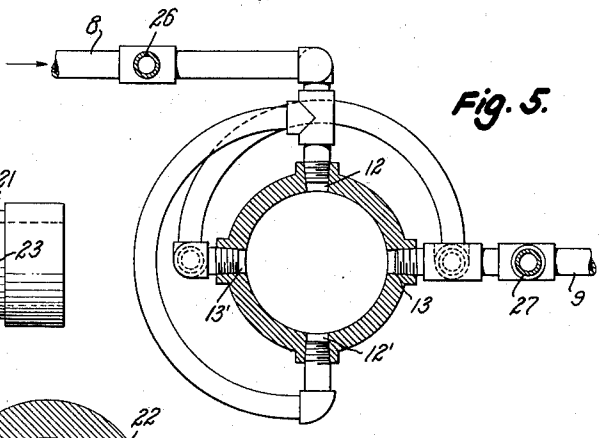
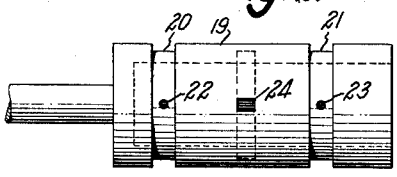


Fig. 5.

Fig. 2.



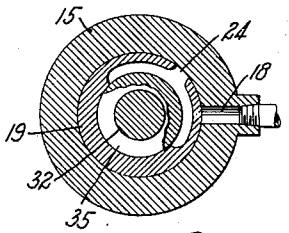


Fig. 3.

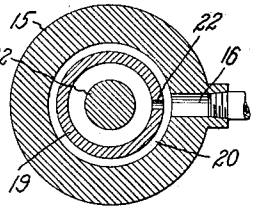


Fig. 4.

INVENTOR

Franklin F. Offner

BY Pierce, Scheffler & Parker

ATTORNEYS

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SERVO SYSTEM

Franklin F. Offner, Chicago, Ill.

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4 Claims. (Cl. 251—25)

This invention relates to hydraulic servo systems and more particularly to a system including a throttle valve inserted in a pipe line for varying the rate of liquid flow through the line and a pilot valve for controlling the setting of the throttle valve.

One object of the invention is to provide a servo system of the hydraulic type consisting of a throttle valve controlled by a pilot valve featuring a new principle of control which assures a high degree of accuracy without the need for maintaining precise tolerances in constructing the various elements employed in the system.

A further object is to provide an improved construction for a servo type throttle valve which features a high degree of stability for various rates of liquid fluid flow through the valve.

Yet another object of the invention is to provide the combination of an improved form of pilot valve and improved form of throttle valve controlled by the pilot valve, the two valves working in conjunction with each other to provide a servo system of exceptional accuracy.

The foregoing as well as other objects and advantages inherent in the invention will become more apparent from the folowing detailed description of a preferred embodiment for the invention and the related drawings in which:

Fig. 1 is a view of the servo system with the throttle and pilot valves shown in central longitudinal sections;

Fig. 2 is a view in elevation of the rotatable sleeve employed in the pilot valve assembly; and

Figs. 3–5 are transverse sections taken on lines 3—3, 4—4 and 5—5 respectively of Fig. 1.

With reference now to the drawings, the servo system is comprised generally of a throttle valve T, an inlet pipe 8 to the valve, an outlet pipe 9 from the valve, a pump 10 of the constant delivery type in the pipe 8 to force liquid fluid such as fuel through the valve into outlet pipe 9 under pressure and a pilot valve P for controlling the setting of the throttle valve T.

The throttle valve T consists of a cylinder 11 containing two identical sets of diametrally disposed ports 12, 12′ and 13, 13′ and a piston 14 slidable within the cylinder across the entrance to such ports to vary the port opening. The ports 12, 12′ are manifolded into the inlet pipe 8 and hence the liquid fuel under pressure enters the valve cylinder 11 below piston 14 through these ports. The dual opposed port arrangement is not absolutely necessary but is preferred so as to balance out the lateral forces on the piston attributable to pressure of the incoming liquid.

The other set of opposed ports 13, 13′ are displaced 90° from the ports 12, 12′ but are located in the same position as the latter in relation to the cylinder 11. That is, the centers of all four ports are located in a common plane perpendicular to the longitudinal axis of the cylinder. Ports 13, 13′ are manifolded into the outlet pipe 9.

Flow of liquid through throttle valve T is controlled by varying the position of piston 14 thereby to increase

or decrease the area of the ports 12, 12′ and 13, 13′ uncovered by the piston. The position of piston 14 is controlled by admission of the liquid from the pilot valve P into that portion 11*a* of cylinder 11 above the piston, i. e. at the side of the piston opposite to that which controls the inlet and outlet ports. The cylinder portion 11*a* constitutes a servo chamber.

The pilot valve in its preferred form of construction is comprised of an outer cylindrical casing 15 having an end cap 15*a* secured by screws 15*b*, an inlet port 16, an outlet port 17 and a servo port 18 located intermediate the inlet and outlet ports 16, 17, all the ports being spaced longitudinally of the casing. Journalled for rotation within casing 15 is a valve sleeve 19 provided with an annular groove 20 aligned with inlet port 16, and another annular groove 21 aligned with outlet port 17. An aperture 22 leads from the base of groove 20 through the wall of sleeve 19 into the bore of the sleeve, an aperture 23 similarly leads from the base of groove 21 into the bore of sleeve 19, and a port 24 also leading into the bore of sleeve 19 through the sleeve wall is disposed in alignment with the servo port 18 in casing 15. A pipe connection 26 leads from inlet pipe 8 to port 16, a second pipe connection 27 leads from outlet pipe 9 to port 17, and a third pipe connection 28 leads from servo port 18 to a port 29 leading to the servo chamber 11*a* in the throttle valve cylinder.

Since the liquid flows from pipe 8 to pipe 9 through throttle valve T, it is at a higher pressure in pipe 8 than in pipe 9. The liquid in inlet pipe 8 is thus used as a source of high pressure for servo control and is led to the interior of pilot valve sleeve 19 through pipe 26, groove 20 and aperture 22. In a similar manner, the liquid in outlet pipe 9 is used as the source of low pressure for the servo system, and liquid is returned to it from the interior of sleeve 19 through aperture 23, groove 21 and pipe 27.

Slidable axially in the bore of rotatable sleeve 19 is the valve stem 32 having end lands 33, 34 and an intermediate land 35. The function of land 35 is to selectively control flow of the liquid fluid between servo chamber 11*a* and the pipe connections 26, 27. If valve stem 32 is shifted to the right from the illustrated neutral position, liquid in the pipe 26 at the high pressure of the system, and which is constantly in communication with the interior of the rotatable pilot valve sleeve 19 between the lands 33, 35 of the valve stem because of the annular groove and aperture arrangement described, will be allowed to flow through pipe connection 28 into servo chamber 11*a* each time that the rotating sleeve 19 brings the port 24 into registry with the servo port 18.

In a similar manner, if the valve stem 32 is shifted to the left from the illustrated position, pipe connection 27 is placed in communication with pipe connection 28 for a brief period during each revolution of sleeve 19, and liquid leaves servo chamber 11*a*, passing into outlet pipe 9 via the communication channels thus established.

It will be evident that the percentage of the total time that the liquid can flow from servo chamber 11*a* through pipe 28 into the interior of the pilot valve sleeve 19, or vice versa, will depend upon the size of port 24 at the outer surface of sleeve 19 and of port 18. These are preferably made quite small so that fluid can flow for only a small fraction of the elapsed time required for one revolution of sleeve 19. While port 24 may be made of uniform size throughout its length, as illustrated, the size of port 24 at the inner surface of sleeve 19 is made larger than that at the outer surface of the sleeve to permit a comparatively large amount of instantaneous fluid flow when the pilot valve is displaced. During the remainder of the time, pipe 28 is effectively sealed off.

For example, if pipe 28 communicates with the interior of sleeve 19 10% of the time, and is sealed off 90% of the time, during the latter fraction no liquid can leave servo chamber 11*a*. Thus the servo piston 14 in the throttle valve T will be effectively subject to hydraulic lock, and will be substantially fixed, even though there be leakages around the throttle piston such that the piston would normally tend to drift in position. During the remaining 10% of the time, the motion of the pilot valve stem 32, and the size of porting, is made sufficient that an adequate travel rate of throttle piston 14 may be obtained. Thus by such design of the pilot valve, the accuracy of the servo system is increased, under the assumed 90–10 ratio of porting, by a factor of 10. Rotation of the sleeve 19 in the pilot valve has the additional advantage of preventing development of frictional forces in the pilot valve, and is preferable to "chopping" the liquid flow by rotation of the valve stem relative to the sleeve because it provides a more complete shut-off of the liquid during the periods when the chopper is supposed to be closed.

In the introduction one stated object of the invention is to provide a servo system having a high degree of stability without the necessity for maintaing close tolerances between the various component parts. One factor in achieving this is the construction of the throttle valve T. The opposed inlet ports 12, 12′ are identical in size and shape, and moreover are of the same size and shape as the two opposed outlet ports 13, 13′. Consequently when liquid flows through the valve T, one-half the pressure drop through the valve will occur at the inlet ports 12, 12′ and the other half of the pressure drop occurs at the outlet ports 13, 13′. Thus the pressure in that portion 11*b* of cylinder 11 below piston 14 will be just midway between the pressures in the inlet and outlet pipes 8, 9. This condition will obtain, independent of the position of piston 14 in its cylinder, provided only that some liquid continues to flow through the valve which can be assured if desired by insertion of a stop in the valve for the piston so as to prevent it from completely obstructing the inlet and outlet ports.

In order that the throttle valve piston 14 shall remain stationary at any selected setting, it is necessary that the liquid pressure in servo chamber 11*a* be equal to the pressure below the piston in throttle chamber 11*b* since the piston 14 in the illustrated embodiment is of uniform diameter. This will be true if the stem 32 of pilot valve P is in such a position that pipe 28 communicates equally with the chambers in the pilot valve connected with pipes 26 and 27. That is, land 35 must be in such relation to servo port 24 that equal leakages flow between pipe 28 and pipe 26, as flow between pipe 28 and pipe 27. That is, the pressure in pipe 28 and thus in chamber 11*a*, will be midway between the pressures in tubes 26 and 27, i. e. midway between the pressures in pipes 8 and 9. As illustrated, land 35 is of the same width as port 24 and in general, leakage balance will occur when the land is centered on the port which is the position depicted. However land 35 can be narrower or wider than port 24 without altering the principle of the invention since there will always be some leakage.

It is my theory that the leakage between pipes 26 and 28 will be equal to that between pipes 28 and 27 when the pressure drops occurring in the pilot valve between these pairs of pipes are in the same ratio as the ratio of the pressure drops occurring in the inlet orifices 12, 12′ and the outlet orifices 13, 13′ of the throttle valve.

Since the pressure in chamber 11*a* is the same as that in chamber 11*b*, there will be no liquid flow between them even though there be clearance between piston 14 and the wall of cylinder 11. Thus the clearance between this piston and its cylinder is not critical. Likewise, such equality of pressure is maintained by a constant position of the pilot valve stem 32, independent of the position of throttle piston 14, so long as there are equal pressure drops in ports 12, 12′ and 13, 13′.

Equality of pressure drop in these ports is most simply obtained but it should be mentioned that it is not necessary that equal pressure drops in ports 12, 12′ and 13, 13′ occur. They can be in any desired fixed ratio. However, if the selected pressure drops as between the inlet and outlet ports of the throttle valve be other than equal, a corresponding change must be made in the equilibrium position of the pilot valve to maintain equality of leakage between pipes 26 and 28 as between pipes 27 and 28, despite the existence of a difference between the two pressure drops.

Because of the pressure differential between the liquid in servo pipes 26, 27 and pipe 28 there will always be a tendency for liquid to leak past the land 35 in pilot valve P either to or from servo chamber 11*a*. With the type of servo system herein described wherein the pressure is ported into the pilot valve, this tendency is largely balanced out. With less stable systems, however, such leakage can be a source of material error.

Operation of the system should be clear from the above description. However by way of a brief summary, movement of the pilot valve stem 32 to the right from the illustrated neutral position will effect a flow of liquid into servo chamber 11*a* since the pressure in the latter will then be greater than that in chamber 11*b*. Piston 14 is thus caused to move further downward in the cylinder 11 and close off more of the port openings 12, 12′ and 13, 13′ thus effecting a reduction in rate of liquid flow through valve T. Conversely, movement of valve 32 to the left from the illustrated position will effect a flow of liquid from servo chamber 11*a* since then the pressure in the latter will be less than that in chamber 11*b*. Piston 14 is thus caused to move to a more upward position and uncover more of the port openings 12, 12′ and 13, 13′ thus effecting an increase in rate of liquid flow through valve T. Piston 14 will continue to move in the selected direction so long as the stem 32 of the pilot valve is held in a displaced position and is stopped by returning the pilot valve stem 32 to the neutral position.

In conclusion, I wish it to be understood that while the illustrated construction constitutes a preferred embodiment for my invention, various minor changes may be made in the construction and arrangement of the component parts in the system without however departing from the spirit and scope of the invention as defined in the appended claims.

I claim:

1. In a hydraulic servo system, the combination comprising; a throttle valve adapted to be inserted in a pipe line to control liquid fluid flowing through the line under pressure, said valve including a casing providing a throttle chamber having a high pressure fluid inlet port thereto and a lower pressure fluid outlet port therefrom, a piston slidable in said casing across said ports to adjust the degree of port opening, the space in said casing at the piston end opposite that controlling said ports constituting a servo chamber; a pilot valve having a high pressure inlet port, a lower pressure outlet port, a servo port, and a valve member for establishing communication selectively as between said inlet port and servo port or between said outlet port and servo port; a pipe connection between the servo port on said pilot valve and the servo chamber in said throttle valve, and pipe connections leading respectively from the inlet and outlet ports on said pilot valve to the pipe line at the high and low pressure sides of said throttle valve, said inlet and outlet ports of said throttle valve being so contoured as to provide pressure drops at said ports remaining in constant proportion to each other as said throttle valve piston is displaced whereby the pressure difference between said throttle chamber and the inlet side to said throttle valve remains in fixed ratio to the pressure dif-

ference between said throttle chamber and the outlet side of said throttle valve.

2. In a hydraulic servo system for use in controlling flow of liquid under pressure in a pipe line, the combination comprising; a throttle valve including a servo chamber, a throttle chamber, inlet and outlet ports for the liquid to and from said throttle chamber and a piston disposed in said throttle and servo chambers and slidable to cover and uncover said ports; a pilot valve including a casing having inlet, outlet and servo ports and a piston slidable in said casing across said ports for controlling liquid flow between said ports; fluid connections leading from the pipe line at the inlet and outlet sides of said throttle valve to the inlet and outlet ports respectively of said pilot valve; and a fluid connection leading from the servo port of said pilot valve to the servo chamber of said throttle valve, said inlet and outlet ports of said throttle valve being so contoured as to provide pressure drops at said ports remaining in constant proportion to each other as said throttle valve piston is displaced, whereby the pressure difference between said throttle chamber and the inlet side to said throttle valve remains in fixed ratio to the pressure difference between said throttle chamber and the outlet side of said throttle valve.

3. A hydraulic servo system as defined in claim 2 wherein said inlet and outlet ports of said throttle valve

are alike thereby to establish in said throttle chamber a fluid pressure midway between the fluid pressures at the said inlet and outlet sides of said throttle valve.

4. A hydraulic servo system as defined in claim 2 wherein said inlet and outlet ports of said throttle valve comprise respectively a pair of oppositely disposed inlets, and a pair of oppositely disposed outlets arranged normal to said pair of inlets.

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