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HYDRAULIC REGULATING VALVE

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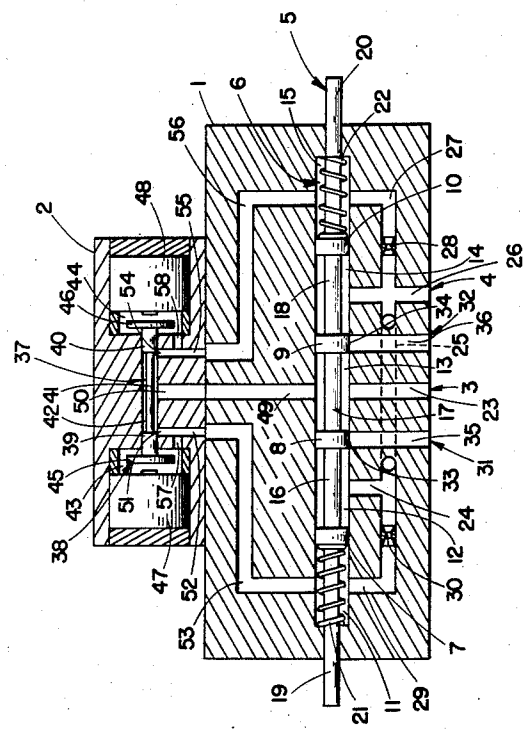


FIG. 1

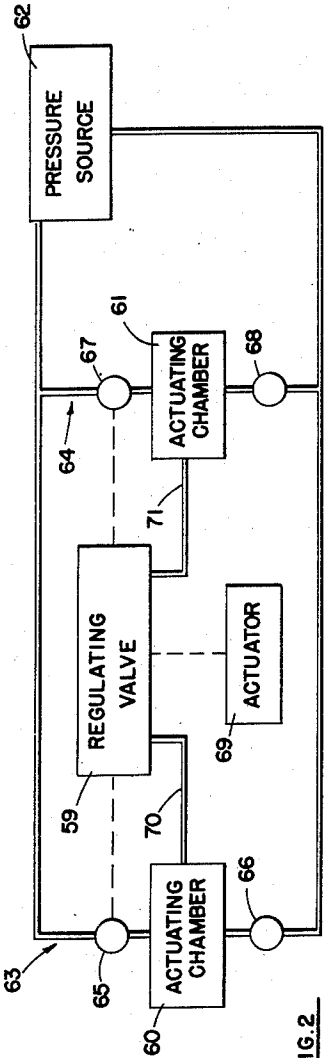


FIG. 2

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HYDRAULIC REGULATING VALVE

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2 Claims. (Cl. 137—623)

This invention relates to hydraulic regulating valves, and particularly to an improved pilot valve useful in controlling the actuation of a large control valve.

When the use of a large control valve is necessary in order to obtain a sufficiently high power output, the inertia of the valve piston has been found to be too high to permit actuation with high sensitivity and good linearity by ordinary means. It has been found necessary to slave the main control valve to a much smaller pilot valve. The pilot valve has a light piston which has little inertia, and hence can be actuated with very good sensitivity by various electronic and mechanical means. The small pilot valve is used to control the pressure differential between two actuating chambers which, in turn, causes movement of the main control valve piston. It has further been found desirable to permit the operator to override the pilot valve temporarily and move the control valve manually without affecting the setting of the pilot valve.

It is an object of this invention to produce a pilot valve which actuates a control valve with improved sensitivity.

It is another object of this invention to produce a pilot valve which actuates a control valve with better linearity.

It is another object of this invention to produce a hydraulic valve useful in maintaining a constant pressure differential between two actuating chambers.

It is another object of this invention to produce a hydraulic valve which utilizes the hydraulic pressure drop across the valve opening to regulate the opening of the valve.

It is another object of this invention to provide a valve slaved to a pilot valve but which permits optional manual operation of the valve without affecting the sensitivity of the control by the pilot valve.

Other objects of invention will become apparent from the following description taken in connection with the accompanying drawings, in which

Fig. 1 is a sectioned view of the preferred embodiment of the improved pilot valve contemplated by this invention;

And Fig. 2 is a schematic drawing utilizing the hydraulic valve contemplated by this invention.

Referring to Fig. 1, a hydraulic control system is shown consisting of control valve block 1 and pilot valve block 2. Control valve block 1 has inlet port 3 to which is connected a source (not shown) of hydraulic pressure and outlet port 4. Control valve piston 5 is fitted to slide freely in cylindrical chamber 6. Piston 5 has four lobes 7, 8, 9, and 10 dividing cylindrical chamber 6 into sealed subchambers 12, 13, and 14, and piston actuating chambers 11 and 15. Lobes 7, 8, 9, and 10 of piston 5 are spaced by reduced connecting rods 16, 17, and 18. Extension rods 19 and 20 of piston 5 are provided to permit manual operation of the control valve piston. Piston return springs 21 and 22 are positioned in actuating chambers 11 and 15, respectively, to normally maintain piston 5 in the neutral position.

Sealed chamber 13 is connected to inlet port 3 by means of duct 23. Sealed chamber 12 is connected to outlet port 4 by means of ducts 24 and 25. Sealed chamber 14 is connected to outlet port 4 by means of duct 26. Actuating chamber 15 is connected to outlet port 4 by means of duct 27. Duct 27 has a fixed restrictive orifice 28 which materially retards the flow of fluid between chamber 15 and outlet port 4. Actuating chamber 11 is connected to outlet port 4 by means of ducts 29 and 25. Duct 29 has a fixed restrictive orifice 30 which materially retards the flow of fluid between chamber 11 and port 4. Actuating ports 31 and 32 are connected to openings 33 and 34 of cylindrical chamber 6 by means of ducts 35 and 36, respectively.

Pilot valve block 2 has a cylindrical chamber 37 in which pilot valve piston 38 is fitted to slide freely longitudinally. Piston 38 has two lobes 39 and 40 separated by reduced connecting rod 41. Lobes 39 and 40 of pilot valve piston 38 are spaced to form sealed subchamber 42 and end chambers 43 and 44. Armature buttons 45 and 46 in end chambers 43 and 44, respectively, are secured to the ends of piston 38. Solenoids 47 and 48 are positioned in end chambers 43 and 44 to attract armature buttons 45 and 46, respectively.

Sealed chamber 42 is connected to center chamber 13 by means of ducts 49 and 50. Variable orifice 51 is connected to actuating chamber 11 by means of ducts 52 and 53. Variable orifice 54 is connected to actuating chamber 15 by means of ducts 55 and 56. End chamber 43 is connected to duct 52 by means of duct 57. End chamber 44 is connected to duct 55 by means of duct 58.

In operation, the hydraulic pilot valve of Fig. 1 is used to actuate control valve piston 5 which regulates the direction and rate of flow of hydraulic fluid to a double-acting cylinder (not shown) connected to actuating ports 31 and 32. Since openings 33 and 34 are completely covered by lobes 8 and 9 when control valve piston 5 is in the neutral position, as shown in Fig. 1, no fluid is initially allowed to flow to the double-acting cylinder. There is, however, a continuous circulation of hydraulic fluid through the pilot valve circuit. Variable orifices 51 and 54 are maintained partly opened at all times by the spacing of lobes 39 and 40. Hydraulic fluid enters port 3 and passes through duct 23, chamber 13, and ducts 49 and 50 into chamber 42. In chamber 42, the flow of the fluid divides into two parallel paths. One of these paths comprises variable orifice 51, ducts 52 and 53, actuating chamber 11, duct 29, restrictive orifice 30, duct 25, and outlet port 4. The other path comprises variable orifice 54, ducts 55 and 56, actuating chamber 15, duct 27, restrictive orifice 28, and outlet port 4. By continuously circulating fluid through both paths of pilot valve circuit, the formation of air bubbles in the circuit is eliminated. Any formation of air bubbles in the pilot valve circuit has a detrimental effect on damping, resulting in poorer sensitivity.

The position of pilot valve piston 38 is determined by the relative magnitude of the tractive forces caused by the currents in solenoids 47 and 48. Initially a bias D.-C. voltage is applied to each of solenoids 47 and 48, causing them to exert equal and opposite tractive forces on piston 38. Superimposed on the D.-C. bias voltage is a low amplitude high frequency A.-C. voltage of from 200 to 400 cycles per second which is applied to each of solenoids 47 and 48. This high frequency voltage is applied to solenoid 47, 180° out of phase to that applied to solenoid 48. This low amplitude high frequency voltage causes a small longitudinal oscillation of pilot valve piston 38 to preclude the adverse effects of static friction on the valve piston. The valve of this invention therefore operates with improved sensitivity due to the elimination of static friction by a minute high frequency longitudinal oscillation of the piston. Since the mass of

the control valve piston is much greater than that of the light pilot valve, the control valve will not follow the high frequency oscillation of the pilot valve.

For purposes of illustrating the excellent linearity obtained by the pilot valve contemplated by this invention, assume the D.-C. bias voltage applied to left solenoid **47** is increased while the D.-C. bias voltage applied to right solenoid **48** is decreased. The change in the relative magnitude of the tractive forces to which piston **38** is subjected, causes pilot valve piston **38** to be displaced longitudinally to the left. The movement of lobe **39** of piston **38** to the left increases the size of variable orifice **51**. This causes a reduction in the pressure drop across orifice **51** with a corresponding increase in the pressure drop across orifice **30**. The resistance to flow of the other elements in the fluid path is negligible. The movement of lobe **40** of piston **38** to the left decreases the size of variable orifice **54**. This results in increasing the pressure drop across orifice **54**, while the pressure drop across orifice **28** decreases. The resistance to flow of the other elements in this fluid path is negligible.

The redistribution of the pressure drops in the two fluid paths results in an increase of the pressure in duct **52** and actuating chamber **11**, while there is a decrease of the pressure in duct **55** and actuating chamber **15**. The increased pressure in actuating chamber **11** coupled with the decreased pressure in actuating chamber **15** causes control valve piston **5** to move to the right. Movement to the right of lobes **8** and **9** results in the uncovering of openings **33** and **34**. Actuating port **32** is now connected to inlet port **3** through chamber **13**. Actuating port **31** is connected to outlet port **4** through chamber **12**.

The rate of flow of the fluid through actuating ports **31** and **32** is determined by the distance piston **5** moves to the right. This distance is determined by the point at which the force on piston **5** due to the pressure differential between chambers **11** and **15** is exactly balanced by the force on piston **5** exerted by piston return spring **22**.

Due to connecting duct **57**, chamber **43** is continuously subjected to the same pressure as that in duct **52** and chamber **11**. Similarly, due to duct **58**, chamber **44** is continuously subjected to the same pressure as that in duct **55** and chamber **15**. Therefore, the hydraulic pressure in end chamber **43** and actuating chamber **11** is always the same. Correspondingly, the hydraulic pressure in end chamber **44** is always the same as the hydraulic pressure in actuating chamber **15**.

Since the pressure in chamber **43** is increased while the pressure in chamber **44** is decreased when piston **38** is moved to the left, a restraining force is imposed on piston **38** tending to return the piston to the neutral position. This restraining force is equal to the product of the pressure differential and the cross-section area of lobe **39**. At some predetermined value of pressure differential the restraining force acting on piston **38** is equal and opposite to the resultant of the tractive forces of solenoids **47** and **48**. Piston **38**, thereafter, assumes a new position around which it continues the minute longitudinal oscillations. The pressure differential between actuating chambers **11** and **15** is therefore determined solely by the magnitude of the resultant of the tractive forces of solenoids **47** and **48**. It is therefore to be noted that any variation in the source pressure applied between inlet port **3** and outlet port **4** merely causes a compensating movement of control valve piston **38** sufficient to maintain the hydraulic pressure differential between chambers **43** and **44** at a constant predetermined value. This is clear when the forces acting on piston **38** are analyzed. The tractive forces acting on piston **38** are proportional to the magnitude of the D.-C. applied voltages. The resultant of the tractive forces is constant for a given value of D.-C. applied voltages over the small range of movement of pilot valve piston **38**. Opposing this constant resultant force is the force due to the pressure differential between chambers **43** and **44**. Since piston **38** always moves a direction and distance necessary to maintain a balance between these forces, the pressure differential is made solely dependent on the relative voltages applied to solenoids **47** and **48**.

Extension rods **19** and **20** of piston **5** permit manual control over the control valve overriding the pilot valve control. The manual manipulation of piston **5** does not affect the setting of the pilot valve which continues to maintain the desired pressure differential between chambers **11** and **15**. Upon removal of the manual override, control valve piston **5** again is positioned in accordance with the setting of the pilot valve.

It is contemplated that the tractive forces exerted on piston **38** by solenoids **47** and **48** can be provided by permanent magnets. Variations in the relative tractive forces are then provided by electromagnets wound around the permanent magnets. It is further contemplated by this invention that other means may be used to actuate pilot valve piston **38**. The means used may be either electronic or mechanical. It is only desirable that the means used be capable of maintaining a constant force over the range of movement of piston **38**.

In the schematic drawing of Fig. 2, a regulating valve **59** is used to regulate the pressure differential between actuating chambers **60** and **61**. Two parallel hydraulic paths **63** and **64** are connected across a pressure source **62**. Path **63** comprises a variable orifice **65**, actuating chamber **60**, and fixed orifice **66**. Hydraulic path **64** comprises variable orifice **67**, actuating chamber **61**, and restrictive orifice **68**. Variable orifices **65** and **67** are always maintained in a slightly open position in order to insure continuous circulation of hydraulic fluid. Variable orifice **65** is varied inversely to variable orifice **67** by regulating valve **59**. An actuator **69** exerts a displacement force of a predetermined magnitude on a piston of regulating valve **59**. This displacement force is opposed by the pressure differential between actuating chambers **60** and **61**. The pressure differential between actuating chambers **60** and **61** is conveyed to opposite sides of the piston in regulating valve **59** by means of ducts **70** and **71**.

In operation, a constant pressure differential is obtained between actuating chambers **60** and **61** despite small fluctuations in the pressure supplied by pressure source **62**. This pressure differential is determined by the amount of force exerted on the piston of regulating valve **59** by actuator **69**. If there is a decrease in pressure from the pressure source the pressure differential between actuating chambers **60** and **61** tends to decrease. This decrease in the pressure differential results in a decrease in the restraining force acting against the piston of regulating valve **59**. The piston therefore moves in a manner necessary to readjust variable orifices **65** and **67** to increase the pressure differential between chambers **60** and **61**. When the pressure differential has reached its previous value the movement of the piston of regulating valve **59** will cease since the restraining force caused by the pressure differential will again exactly equal the force exerted by actuator **69**. Variable orifices **65** and **67**, regulating valve **59**, actuator **69**, and ducts **70** and **71** are preferably made similar to the solenoid pilot valve of Fig. 1. It is, however, contemplated that a different type of actuator could be used. The only requirement being that the actuator exerts a constant force of a predetermined value against the piston of regulating valve **59**.

Although the invention has been described and illustrated in detail, it is to be clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and

scope of this invention being limited only by the terms of the appended claims.

I claim:

1. Regulating means comprising a pair of fluid channels arranged in parallel, a single fluid channel, means causing flow of fluid to said pair of channels from said single channel, means for restricting flow of fluid in said pair of channels; a pilot valve including a cylindrical chamber connected near one end to one of said pair of channels, near the other end to the other of said pair of channels, and at its central portion to said single channel; said pilot valve further including a pilot valve stem having a central portion of reduced diameter and two end lobes filling said chamber, said end lobes being separated by a distance slightly greater than the distance between the intersections of said pair of channels with said chamber, a first pressure balancing chamber opening into one end of said cylindrical chamber, a second pressure balancing chamber opening into the other end of said cylindrical chamber, conduit means connecting each of said pair of channels to the said balancing chamber adjacent thereto and means for actuating said pilot valve stem longitudinally in said cylindrical chamber

to thereby control the differential pressure between said pair of channels.

2. A device as recited in claim 1 and further comprising a hydraulic regulating valve actuable in response to said differential pressure.

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