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[54] DEVICE FOR DIVIDING THE FLOW OF LIQUID INTO TWO PARTS

1 Claim, 2 Drawing Figs.

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[56] **References Cited**

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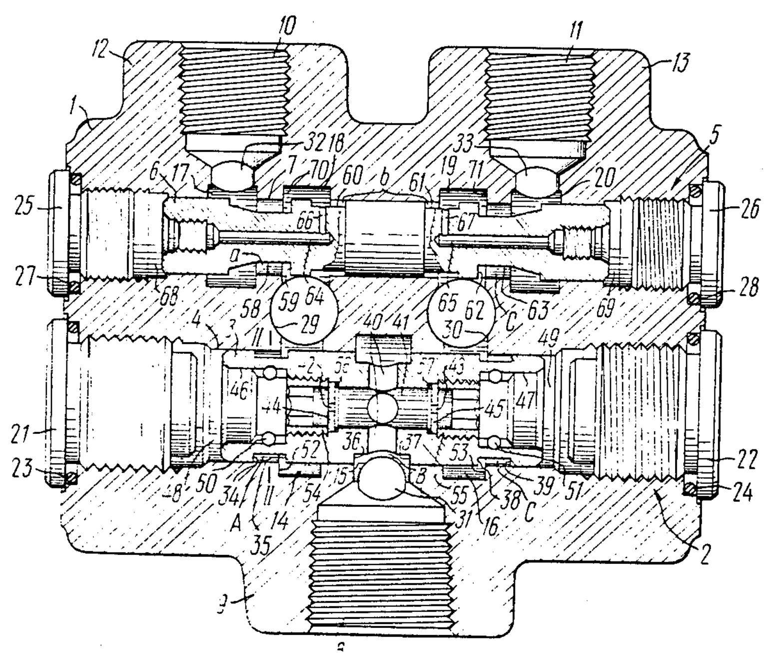
ABSTRACT: A device for dividing the flow of liquid into two parts comprises a control valve with two constant-section flow restrictors and a pair of restrictor means and another control valve with another pair of restrictor means arranged downstream of the first pair. Each restrictor means forms a variable transversal section slot whereas the outlet of each restrictor means of the first pair is connected to the inlet of one of the restrictor means of the second pair that permits division of the flow of liquid with a great accuracy under all operating conditions.



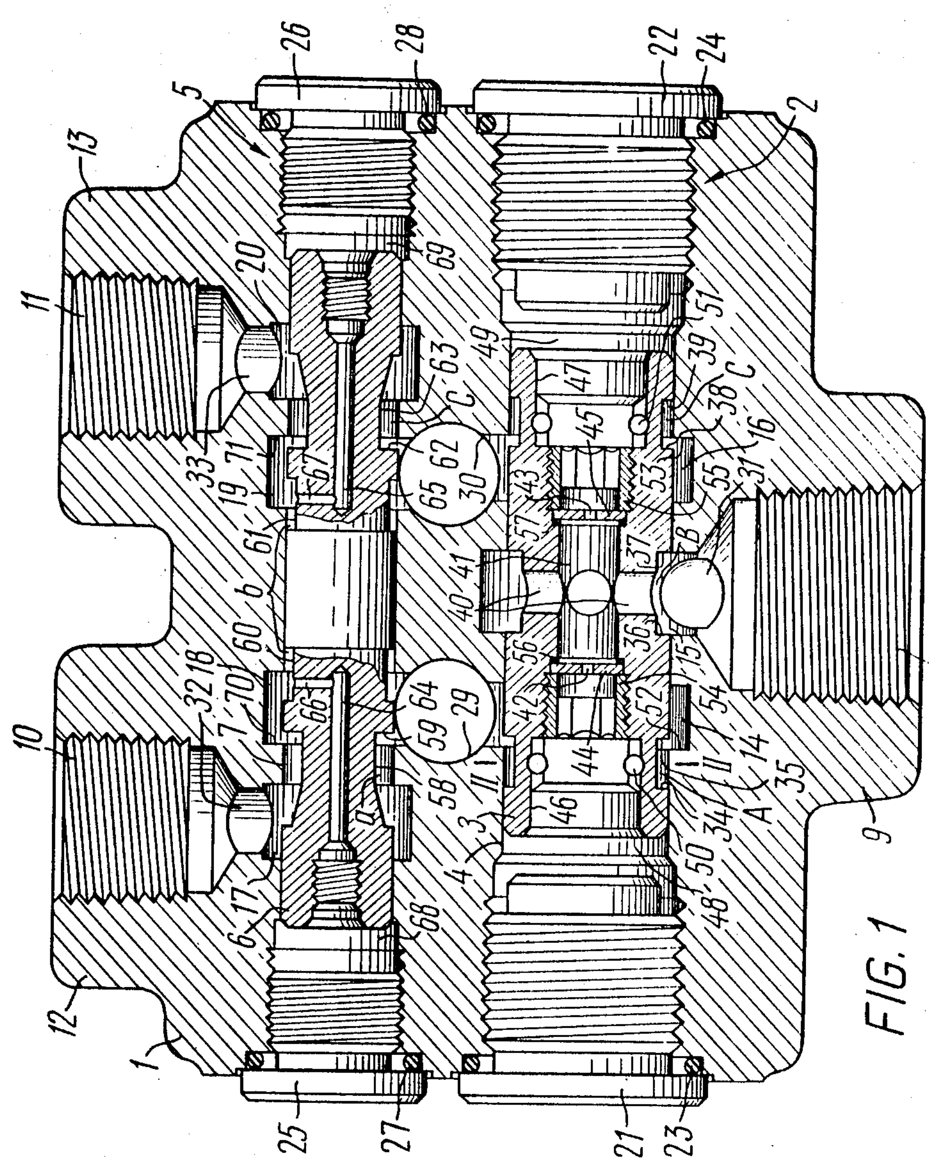


FIG. 1

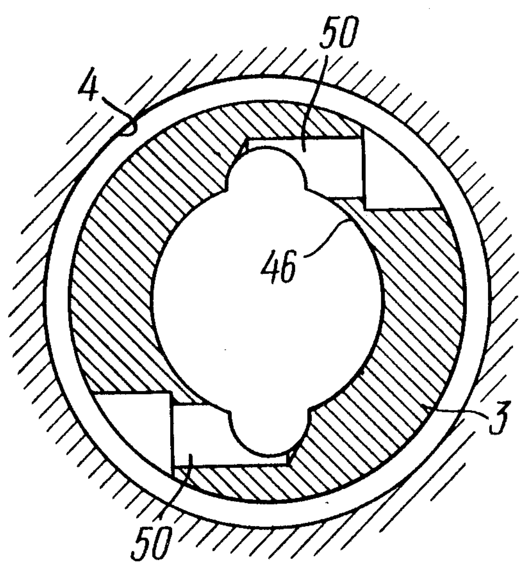


FIG. 2

DEVICE FOR DIVIDING THE FLOW OF LIQUID INTO TWO PARTS

The present invention relates to the devices for dividing the flow of liquid into two parts and is intended for use in the hydraulic systems of machines, mainly for the purpose of synchronizing the motions of the actuating elements (hydraulic motors, power cylinders) regardless of the value of the external loads applied to said elements.

Known in the art are devices for dividing the flow of liquid comprising a housing with one inlet and two outlet holes with a movable control valve installed in its longitudinal hole and forming end chambers by the edges of the hole.

Inside the control valve there is an intermediate chamber connected with an inlet hole of the device whereas at the edges of the intermediate chamber there is a pair of restrictors of a constant section. Inside the control valve there is also a pair of passages each of which on one hand is connected through one of the constant restrictors to the intermediate chamber of the control valve, whereas on the other hand it is connected to one of its end chambers. The device comprises a pair of restrictors each of which is formed by restrictor elements of the control valve surface in combination with restrictor elements of the hole forming a slot varying the area of its transversal section during longitudinal motion of the control valve, under the effect of the difference of liquid pressure in the end chamber.

Each restrictor has an inlet and outlet, the inlet thereof being connected to one of the passages of the control valve, whereas the outlet is connected to one of the outlet holes of the device.

The liquid flow to be supplied is divided inside the control valve into two parts. Each branch of the liquid flow passes through the flow restrictors of constant and variable cross sections.

If the actuating elements communicating with the outlet holes of the device are subjected to equal external loads, that is, offer identical resistances to the flow of the service fluid, the throttling means occupies the middle position so that the resistances of both variable-section flow restrictors are the same.

The pressure drops through the constant-section flow restrictors are the same and so are the consumptions of liquid in both branches of the device.

If the actuating elements communicating with the outlet holes of the device are subjected to different external loads, that is offer different resistances to the flow of the service fluid, the throttling means starts moving towards the outlet hole which offers a lower resistance thereby reducing the area through the variable-section flow restrictor at this end and increasing that through the variable-section flow restrictor at the opposite end. This movement proceeds until the pressures in the closed end chambers of the control valve become equal. Thus the throttling means comes again to the position of equilibrium.

Thus, there appears identical pressure drops on the constant-section flow restrictors, the pressures in the closed end chambers become equalized by throttling means and, as a consequence, the liquid consumption in both branches of the device is also the same.

However, experiments have shown, that at the rates of liquid flow exceeding 20 or 30 l./min. and at a considerable difference of pressures in the channels communicating with the outlet holes, the equilibrium of the valve spool becomes seriously affected by the different of the axial components of the hydrodynamical reaction forces that arise while the liquid flows through the variable-section flow restrictors. Each of these forces tends to move the valve spool towards the smaller section of the variable-section flow restrictors. Inasmuch as this force is approximately proportionate to the squared velocity of the liquid flow, there arises in the variable-section flow restrictor with a smaller cross-sectional area a considerably greater hydrodynamical reaction force than in the other variable-section flow restrictor. Therefore the difference of the axial components of the hydrodynamical reaction forces tends to move the control valve towards still further reduction of the area through the variable-section flow restrictor of the side subjected to a lesser load and whose cross section is smaller. Consequently, the equilibrium of the throttling means or spool is ensured at different pressures in the closed end chambers of the control valve which results in different pressure drops through the constant-section flow restrictors and, logically, in different rates of liquid flow through the branches of the device for dividing the liquid flow. It has also been established experimentally that the difference of pressures in the closed end chambers of the control valve under the considered service conditions does not exceed 1 kg./cm.^{2} which, however, is enough to cause a flow division error varying from 2 to 10 percent depending on the design and workmanship of the device.

Moreover, at high absolute pressures (from 200 to 300 kg./cm.^{2}) the flow division errors grow considerably owing to the leakage of liquid through the control valve clearances from the pressure chambers into the nonpressure chambers.

During prolonged operation of the known devices for dividing the liquid flow at different but prolonged loads in the channels communicating with the outlet holes of the devices there arises a real danger of hydraulic jamming of the throttling means or spool which may lead either to a considerable increase of the flow division error or to a complete failure of the device with a resultant breakdown of the equipment.

An object of the invention resides in eliminating the aforesaid disadvantages.

The main object of the invention resides in providing a device for dividing the liquid flow which would allow the flow to be divided into two parts with a high degree of precision without increasing the energy losses, would function under any service condition with equal precision and in which the leakage of liquid through the control valve clearances would not affect the precision of its operation.

This object is achieved by providing a device for dividing the liquid flow into two parts comprising one movable control valve and having inside an intermediate chamber connected to the inlet hole of the device, a pair of constant restrictors by the edges of the intermediate chamber and two passages each of which on one hand is connected to the intermediate chamber through one of the constant restrictors whereas on the other hand it is connected to one of the end chambers and provided with a pair of restrictor means arranged downstream of the constant restrictors and providing a slot varying the area of its transversal section during longitudinal motion of the control valve passages, and according to the present invention, there is another control valve movable in another longitudinal bore of the housing forming each of them by its end another end chamber and this control valve has a pair of channels and a pair of other restrictor means each of which is formed by restrictor means of the surface of this control valve and restrictor elements of another hole creating another slot varying the area of its transversal section during longitudinal motion of this control valve under the effect of the difference of pressures in its end chambers, whereas each restrictor means has an inlet and outlet, and whereas the housing is provided with two intermediate holes each of which at one hand is connected to the outlet of one of the restrictor means of the first control valve and on the other hand it is connected to the inlet of one of the restrictor means of the other control valve and through one of its channels to one of its end chambers; an output of each of the restrictor means of the other control valve being connected to one of the outlet holes of the device.

Now the invention will be described in detail by way of example with reference to the accompanying drawings, in which:

FIG. 1 is a longitudinal section of the device for dividing the flow of liquid into two parts, according to the invention; and

FIG. 2 is a section taken along line II–II of FIG. 1, according to the invention.

The body 1 (FIG. 1) of the device for dividing the liquid flow, resembling a prism in shape, comprises in its lower portion 2 a movable first spool 3 in the longitudinal bore 4 and in the upper portion 5 of the housing there is also installed another movable spool 6 in the longitudinal bore 7.

The hole or port 8 is made in the boss 9 of the housing 1 and is used as an inlet port of the device. The holes or ports 10 and 11 are made respectively in the bosses 12 and 13 of the housing and are used as outlet ports of the device.

The screw 4 has concentric recesses 14, 15 and 16 while the bore 7 has concentric recesses 17, 18, 19 and 20. The bore 4 is closed on both sides with screwplugs 21 and 22 with sealing rings 23 and 24 while the bore 7 is closed with screwplugs 25 and 26 with sealing rings 27 and 28.

The body has intermediate ports 29 and 30. The port 29 communicates the recess 14 with the recess 18 while the port 30 communicates the recess 16 with the recess 19. The ports 29 and 30 serve also for connecting pressure gauges (if they are needed).

The recess 15 communicates with the inlet hole 8 through an oval hole 31 while the recesses 17 and 20 communicate with the outlet holes 10 and 11 through oval holes 32 and 33.

The spool 3 has channels A, B and C limited, respectively, by the members 34 and 35, 36 and 37, 38 and 39.

The inlet hole 8 communicates through the channel B limited by the members 36 and 37 and through radial holes 40 with the intermediate channel 41 of the spool 3. By the edges of the intermediate chamber 41 there are installed constant restrictors 42 and 43 made in diaphragms 44 and 45. The passages after the constant restrictors formed with recesses 46 and 47 are communicated with end chambers 48 and 49.

The recess 46 is connected by the tangential holes 50 (FIGS. 1, 2) with one outlet channel A of the spool 3 (FIG. 1) formed by the members 34 and 35 while the recess 47 is connected by the tangential holes 51 with the other outlet channel C of the spool 3, formed by the members 38 and 39.

The member 35 of the control valve forms in combination with an element 52 of the recess 14 a slot of the restrictor means whose outlet is communicated to the port 29. The member 38 forms in combination with an element 53 of the recess 16 a further slot of the restrictor means whose outlet is communicated to the port 30.

The diaphragms 44 and 45 are pressed against the inner faces of the recesses 46 and 47 by the plugs 54 and 55 installed on sealing gaskets 56 and 57.

The spool 6 has channels *a*, *b*, *c* limited, respectively, by the walls 58, 59, 60, 61 62 and 63, and internal channels 64 and 65.

The holes 29 and 30 are communicated by the channels 64 and 65 through the radial damping holes 66 and 67 with the corresponding closed end chambers 68 and 69 of the control valve 5. Members 59 and 62 of the spool 6 form in combination with elements 70 and 71 of the bore 7 slots of restrictor means whose outlets are communicated to the outlet holes 10 and 11 of the device (each means to one outlet hole).

The device disclosed in this description functions as follows.

The flow of the service liquid fed into the inlet hole 8 passes through the oval hole 31 and flows into the recess 15 of the body. Thence it flows through the channel B of the spool 3 formed by members 36 and 37 through the radial holes 40 into the intermediate channel 41 and, branching off in two directions, passes through the holes 42 and 43 (which are constant-section flow restrictors) into the closed end chambers 48 and 49. Further, the l liquid flows through tangential holes 50 (FIGS. 1 and 2) and 51 (FIG. 1) and through the throttle opening means formed by the members 35 and 52 on one side and by the members 38 and 53 on the other, into the ports 29 and the throttle opening means formed by the members 59 and 70 on one side and the members 62 and 71 on the other, into the recesses 17 and 20 and further, through the oval holes 32 and 33—into the outlet holes 10 and 11. The liquid pressure is carried from the recesses 18 and 19 through the radial damping holes 66 and 67 and the internal channels 64 and 65 into the closed end chambers 68 and 69 of the spool 6.

The spool 6 is in equilibrium only when pressures in the chambers 68 and 69 are equal. As these chambers are in communication with the ports 29 and 30, the equilibrium of the spool 6 ensures equal pressures in the openings of the throttling means of the spool 3.

If the pressures in the external channels connected to the outlet holes 10 and 11 are equal, the spools 3 and 6 occupy a middle position in which the resistance of the restrictors of both control valves are equal to each other. In this case the pressure drops in both constant-section flow restrictors (holes 42 and 43) become equal which ensures identical rates of liquid flow through these holes.

An increased resistance of the actuating element which is connected to, say, the outlet hole 10 causes a decrease in the pressure drop in the left-hand constant-section flow restrictor (hole 42), and, consequently, a pressure rise in the chambers 68 and 48. Both spools tend to move to the right but the spool 6 during its movement throttles the liquid by its right-hand opening of the throttling means (formed by the walls 62 and 71) thus equalizing the pressure in the recesses 18 and 19, chambers 68 and 69, ports 29 and 30, recesses 14 and 16, and chambers 48 and 49. Therefore, the spool 3 has only a tendency to move but actually stays in place, so that the spool 6 alone moves.

The spool 6 continues moving until the pressures become equal in the recesses 18 and 19, and, consequently, in the closed end chambers 68 and 69 which are communicated with the recesses by the holes 66, 64 and 67, 65.

The equal pressures built up in this manner in the chambers 48 and 49 ensure identical pressure drops in the constant-section flow restrictors 42 and 43 and, consequently, identical consumptions in both branches of the device.

The difference of the axial components of the hydrodynamical reaction forces occasioned in the opening of the throttling means formed by the members 59, 70 and 62, 71 creates a pressure differential in the recesses 18 and 19 and, consequently, in the recesses 14 and 16, this differential not exceeding 1 kg./cm.^{2}. It means that the dividing stage proper, i.e. the spool 3 with the flow restrictors 42 and 43 functions at a pressure difference in the ports 29 and 30 which never exceeds 1 kg./cm.^{2}.

Owing to this, regardless of the relations between the pressures in the outlet holes 10 and 11, the spool 3 performing the dividing functions stays always near the middle position which ensures the equality of the axial components of the hydrodynamical reaction forces occasioned in its opening of the throttling means and a high precision of its operation.

Thus, a higher precision of flow division is achieved without an increase in the power losses.

Leaks of liquid along the clearances in the spool 3 are nonexistant since the pressure in all its chambers (recesses 14, 15, 16 and chambers 48 and 49) is actually the same.

In our example the liquid leaks through the clearances of the spool 6 may take place only from the chamber 69 into the recess 20 (or from the chamber 68 into the recess 17) since it is these chambers between which the maximum pressure difference occurs.

However, these leaks cannot influence the precision of flow division because the recess 20 passes the already divided liquid which flows along two paths to the outlet hole 11, through a slot of the right-hand restrictor means of spool 6 and through the hole 67 and channel 65 into the chamber 69 wherefrom it flows through the clearance between the spool 6 and the body into the recess 20.

Thus, in the device of the present invention for dividing the liquid flow into two parts the liquid leaking between the chambers doesn't exert any influence on the precision of flow division.

Experiments have proven that it is practicable that the spool 3 be set in rotary motion. This rotary motion caused by the reaction moment arising with the liquid passes through the tangential holes 50 and 51 eliminates the effect of static friction upon its sensitivity. If the spool 6 be jammed the spool 3 will move and create such a pressure difference in the chambers **68** and **69** which is necessary for starting from rest the jammed spool **6**. The possibility of jamming of the spool **3** is practically nonexistant, because this spool is always subjected to one and the same pressure and, in addition, is constantly rotating. Jamming, as it is known, occurs only when the liquid leaks through the clearances in the control valve from the high-pressure chambers into those with a considerably lower pressure. Such an interaction of the two control valves ensures a high dependability of the device for the division of the liquid flow.

Thus, the device claimed herein has a number of advantages over the previously known designs. It ensures a higher precision in dividing the liquid flow, without an increase in the losses of power. Moreover, as one can see from the preceding description, the difference of the axial components of the hydrodynamical reaction forces occasioned in the opening of the throttling means exerts no influence on the precision of flow division which allows the device to be utilized for work under a wide variety of conditions with a high degree of precision. The device is completely free of undesirable hydraulic jamming of the spools, which fact also adds to the dependability of the device.

The precision of flow division is not affected by the leaks of the liquid through clearances from the high-pressure chambers into the low-pressure ones.

While the device described above and illustrated in the accompanying drawing is intended for dividing the flow of liquid, the principle of the invention will not change if it is utilized in summators which are likewise designed for synchronizing two power cylinders (or hydraulic motors) though by way of combining two flows in one.

Moreover, it can be used in the hydraulic systems of various machines not only for synchronizing the actuating elements but also in such cases, for example, when it becomes necessary at a certain stage of the operating cycle to deliver only a half (or another fraction) of the flow to the actuating element.

What we claim is:

1. A device for dividing the flow of liquid into two parts comprising a housing having one inlet and two outlet ports; one longitudinal bore in said housing having closed edges; a movable spool shiftable in said longitudinal bore; said longitudinal bore accommodating said movable spool forming at each of the end faces of the spool an end chamber; said spool having therein an intermediate chamber communicating with said inlet port of the device; two constant throttles installed at the edges of said intermediate chamber; said spool having therein a pair of channels each of which communicates with the intermediate chamber through one of the constant throttles and with one of the end chambers; a pair of throttling means downstream of said constant throttles each of which is formed by throttling elements of the surface of said spool in combination with throttling elements of said longitudinal bore and creating a slot varying the area of its transversal section during longitudinal motion of said spool under the effect of a difference of pressures of liquid in said end chambers; said throttling means being arranged at both sides of said inlet port of the device and each having an inlet and outlet, the inlet of the throttling means communicating with one of said channels of said spool; said housing having a further longitudinal bore with closed edges wherein a further spool is installed and forms at its end faces further end chambers; said further spool having a pair of channels, a pair of further throttling means each of which is formed by throttling elements of the surface of the further spool in combination with throttling elements of said further longitudinal bore and creating a further slot varying the area of its transversal section during longitudinal motion of the further spool under the effect of a difference of liquid pressures in its end chambers; said channels and throttling means of the further spool being arranged at both sides of said inlet bore of the device and each of said further throttling means having an inlet and outlet; said housing having two intermediate bores each of which said bores communicates with the outlet of one of the throttling means of the first spool and communicates with the inlet of one of the throttling means of the further spool and through one of the channels in said further spool with one of its end chambers; the outlet of each of the throttling means of the further spool communicating with one of said outlet ports of the device.