ABSTRACT: A sliding plate type directional control valve comprising a movable or sliding plate member disposed within the valve chamber for sliding movement, said movable member having, solely or together with a valve body member, stepped fluid passages each comprising a large diameter passage portion and a small diameter passage portion, each of said stepped fluid passages is always in communication with either one of the valve ports, a piston being disposed in each of the large diameter portions, the cross-sectional area of said large diameter passage portion being equal to or greater than the effective pressure acting area of the corresponding port so that the movable member may be constantly urged toward the valve port under the influence of the pressure difference acting thereon.
SLIDING PLATE TYPE DIRECTIONAL CONTROL VALVE

BACKGROUND OF THE INVENTION

The present invention relates to a fluid control valve, and more particularly to a sliding plate type directional control valve having a sliding member disposed within valve chamber for sliding movement so as to control fluid flow.

In the past, as means for providing a directional control of fluid flow, there have been proposed two different types of directional control valves, namely, a spool valve and a sliding plate type valve. However, both of these known types have disadvantages. The spool type directional control valve, a cylindrical spool is slidably received within a valve body which has a plurality of ports such as a pump port, tank port and one or more cylinder ports respectively communicating with a fluid pump, fluid reservoir or tank and one or more fluid cylinders or the like through suitable pipings. Said spool is provided with a plurality of circumferential grooves and serves to effect communication between selected two of said ports when it is slidably and axially moved. In other words, when the spool is moved in the direction, the pump port and the tank port are respectively put into communication with said other of the cylinder ports and said one of the cylinder ports. Thus, the flow of fluid can be switched over simply by the axial sliding movement of the spool. In this type of directional control valve, problems have been encountered in that a foreign material enters between the spool and the valve body causing sticking of the valve spool, that there often occurs fluid leakage from the gap between the spool and the valve body, and that, through the extended usage, either or both of the spool land and the inner wall surface of the valve chamber are subjected to wear and results in an excessively large clearance between them so that the volumetric efficiency of the valve is substantially reduced.

In order to overcome the above described disadvantages, a sliding plate type directional control valve has been proposed. In this type of valve, a valve body is constructed by a pair of port members having a pump port and one or more cylinder ports respectively disposed so as to form a valve chamber therebetween, and an intermediate member disposed between the port members and having a tank port. Within said valve chamber, a sliding plate having a plurality of fluid passages is axially slidably received.

It is important to note that the valve of this type includes a wear compensation mechanism for compensating the possible wear of the valve components which may be experienced through the extended usage of the valve. To this end, in this type of valve, the sliding plate is disposed within the valve chamber with a sufficient clearance between it and the port members so that the sliding plate may not directly contact with either of the port members. At each port, the clearance between the sliding plate and the port member is sealed by means of a so-called balanced piston which is disposed in the fluid passage communicating with a port and is resiliently pushed onto the surface of the sliding plate by thrust of the spring so that the balanced piston may sealingly engage with the sliding plate for preventing the leak-off from the gap between the sliding plate and the port member. The piston may be so constructed that the differential fluid pressure acting thereon may assist to push it toward the sliding plate. By this arrangement, the internal fluid leakage in the valve can be effectively prevented, and moreover any wear of the valve components can be compensated.

However, the sliding plate type valve is also disadvantageous in that all of the ports are simultaneously opened or put into communication during operation or transition period of the sliding plate in which the plate is moved from one position to the other, and therefore the pressure in each port is instantaneously released to zero pressure. Accordingly, this type of directional control valve can have but a few limited uses unless the circuit in which it is disposed are provided with specially designed additional means.

SUMMARY OF THE INVENTION

The present invention is aimed to overcome the disadvantages as encountered in the known types of directional control valves.

The present invention has a particular relation to a directional control valve adapted to be disposed in a fluid circuit including for example a fluid pressure pump and a pressurized fluid operated actuator such as a fluid cylinder for controlling the fluid flow, and more particularly to a sliding plate type directional control valve having a sliding member slidably disposed within a valve chamber for controlling the fluid flow.

An object of the present invention is to provide a directional control valve in which internal fluid leakage is substantially eliminated without any increase of sliding resistance, and which is easily operated and is suitable even as a high pressure valve.

Another object of the present invention is to provide a directional control valve in which all of the ports are prevented from being simultaneously opened even when a transition period in which the sliding member is moved from one position to the other or another position so that the pressurized fluid from the pump port is prevented from escaping into the low pressure or tank port.

A further object of the present invention is to provide a directional control valve in which the sliding resistance is substantially reduced by a perfect pressure balancing arrangement for eliminating any moment acting on the sliding member due to the fluid pressure.

Still another object of the present invention is to provide a directional control valve in which means are incorporated for compensating any wear of sliding surfaces such as the sliding member and the valve body.

Still further object of the present invention is to provide a directional control valve in which the tank port can be subjected to a back pressure by preventing all of the ports from being opened during said transition period.

A further object of the present invention is to provide a directional control valve which may be modified to several different types such as the open-center type, closed-center type or partially open center type, etc., by applying only a simple machining to the sliding member.

Another object of the present invention is to provide a semi-open center type directional control valve or such a valve that can effect an inching action.

Still further object of the present invention is to obtain a directional control valve of such a type that has all of the afore-mentioned and other functions which may be obtainable by a conventional spool valve.

With these and other objects in view, the directional control valve in accordance with the present invention comprises a ported member and movable member provided with stepped fluid passages each of which having a large diameter and a small diameter passage portions, and normally communicating with either the pump port or one of the cylinder ports, a piston being disposed in each of the large diameter passage portions, the cross-sectional area of said large diameter passage portion being equal to or larger than the effective pressure acting area of the corresponding port so that the movable member may be constantly urged toward the ported member under the influence of the differential pressure acting thereon.

In one aspect of the present invention, the stepped fluid passage is provided in a sliding member.

In another aspect of the present invention, a floating member is provided in the valve chamber, and the stepped fluid passage is provided in the floating member or between it and the valve body.
BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:
FIG. 1 is a longitudinal section of a conventional balanced piston type three position four way reciprocating electric solenoid valve;
FIG. 1a is a symbol of the valve shown in FIG. 1;
FIG. 2 is an enlarged sectional view showing in detail the balanced piston employed in the valve shown in FIG. 1; FIG. 3 is a longitudinal section of a conventional three position four way rotary type directional control valve of the balanced piston type, the section being taken along the line III--III of FIG. 4;
FIG. 3a symbolically show the type of the valve shown in FIG. 3;
FIG. 4 is a sectional view taken along the line IV--IV of FIG. 3;
FIG. 5 is a longitudinal sectional view of a hand operated reciprocal type three position four way valve embodying the present invention, the valve being shown in the neutral position;
FIG. 5a is a symbol showing the type of the valve shown in FIG. 5;
FIG. 6 is a sectional view substantially taken along the line VI--VI of FIG. 5;
FIG. 7 is a plan view of the port member employed in the valve shown in FIG. 5;
FIG. 8 is a sectional view substantially taken along the line VIII--VIII of FIG. 7;
FIG. 9 is a sectional view substantially taken along the line IX--IX of FIG. 7;
FIG. 10 is a plan view of the sliding member employed in the valve shown in FIG. 5;
FIG. 11 is a sectional view substantially taken along the line XI--XI of FIG. 10;
FIG. 12 is a longitudinal sectional view similar to FIG. 5, but showing the sliding member shifted to the extreme left position;
FIG. 13 is a sectional view showing a modification of the embodiment shown in FIGS. 5--12, the valve being an all port open type four way valve;
FIG. 13a is a symbol of the valve shown in FIG. 13;
FIG. 14 is a further modification of the embodiment shown in FIGS. 5--12, the valve being a center-bypass type four way valve;
FIG. 14a is a symbol of the valve shown in FIG. 14;
FIG. 15 is a longitudinal sectional view showing the fluid pressure relationship in the valve shown in FIGS. 5--12;
FIG. 16 is a longitudinal sectional view of the second embodiment of the present invention, the valve being a hand operated reciprocal type and shown in the neutral position;
FIG. 16a is a symbol showing the type of the valve of FIG. 16;
FIG. 17 is a plan view of the port member employed in the valve shown in FIG. 16;
FIG. 18 is a sectional view of the port member substantially taken along the line XVIII--XVIII of FIG. 17;
FIG. 19 is a sectional view of the port member substantially taken along the line XIX--XIX of FIG. 17;
FIG. 20 is a plan view of the sliding member employed in the valve shown in FIG. 16;
FIG. 21 is a sectional view of the sliding member substantially taken along the line XXI--XXI of FIG. 20;
FIG. 22 is a plan view of the floating member employed in the valve shown in FIG. 16;
FIG. 23 is a longitudinal sectional view similar to FIG. 16 but showing the sliding member shifted to the extreme left position;
FIG. 24 shows a modification of the embodiment shown in FIGS. 16--23, in which the sliding member has no through hole but each port and the stepped fluid passage is communicated through a separate passage;
FIG. 24a is a symbol of the valve shown in FIG. 24;
FIG. 25 shows a member for subjecting the tank port to a back pressure;
FIG. 25a is a symbol showing the type of the valve of FIG. 25;
FIGS. 26 and 27 show modified stepped fluid passage;
FIG. 27a shows the type of the valve of FIG. 27;
FIG. 28 is a sectional view substantially taken along the line XXVIII--XXVIII of FIG. 27;
FIG. 29 is a longitudinal section of an all port open type four way directional control valve;
FIG. 30 is a longitudinal section of a partial open center type four way directional control valve;
FIG. 31 is a longitudinal sectional view of a center by-pass type four way directional control valve;
FIG. 32 is a longitudinal sectional view of a valve which is provided with a choke between the shifted positions of the sliding member so as to obtain an inching, shock free and flow control features;
FIG. 33 is a longitudinal section of a rotary type three position four way directional control valve;
FIGS. 29a, 30a, 31a, 32a and 33a diagrammatically show the type of the valve of FIGS. 29, 30, 31, 32 and 33 respectively;
FIG. 34 is a plan view of the port member employed in the valve shown in FIG. 33;
FIG. 35 is a plan view of the sliding member employed in the valve shown in FIG. 33;
FIG. 36 is a plan view of the floating member employed in the valve shown in FIG. 33.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, particularly to FIGS. 1 and 1a, there is shown by a longitudinal sectional view a kind of conventional sliding plate type directional control valve, i.e., a reciprocating type two position four way solenoid valve. As shown in the drawing, the valve includes a pair of port members 101 and 102 having a pump port P and a pair of cylinder ports A and B respectively. The port members 101 and 102 are so arranged that a valve chamber 103 is defined therebetween, and an intermediate member 104 is interposed between the port members 101 and 102. The port members and the intermediate member are secured together so as to form a rigid valve body. Within the valve chamber 103, a sliding member 108 is axially slidably received. The sliding member has flow passages 105, 106 and 107. The member 108 is constantly urged toward right by a coil spring 111 which acts through a spring seat 110 on the left end of the sliding member 108. An electric solenoid 109 is disposed at the right hand side of the sliding member 108 and acts, when energized, on the member 108 to urge it toward left. Thus, the sliding member 108 is selectively shifted toward right or left so as to connect the port P selectively to the port A or B through the passage 105 or 107. It has been known, in this type of valve, to provide a wear compensation mechanism for the purpose of preventing fluid leakage from the clearance between the port members 101 and 102 and the sliding member 108 and compensating any wear of the members which may occur through the extended usage of the valve. A typical example of the compensation mechanism is shown in FIG. 1. In the valve construction shown in FIG. 1, the sliding member 108 is arranged with a sufficient clearance with port members 101 and 102 so that the former may not directly contact with the latter. The port members 101 and 102 carries, at each of the passages leading to the ports P, A and B, a so-called balanced piston 112P, 112A or 112B which is urged by means of a spring 113P, 113A or 113B toward the sliding member 108 so as to seal the clearance between the sliding member 108 and the port member 101 or 102 even when either of the members is subjected to wear. The balanced piston is an effective area at the opposite ends so that the pressure difference acting thereon may assist to urge the piston toward the sliding member 108. Thus, when the sliding member 108 is shifted to one of their positions, for example to the position shown in
FIG. 1 in which the port P is connected with the port A through the passage 105 and the tank port T is connected with the port B through the passage 106, the balanced pistons 112P and 112A are urged toward the sliding member 108 by the pressure difference acting thereon and the springs 113P and 113A so as to make a fluid tight contact with it. Therefore, the pressurized fluid from the pump port P is prevented from leaking into the valve chamber and is introduced into an actuator (not shown). Even when either the contact surface of the sliding member 108 and the balanced piston 112 are worn, the fluid tight contact at the contact surfaces can be maintained because the pistons are pushed onto the sliding member 108 by means of the springs 113.

Thus, the known form of sliding plate type directional control valve may be effective in preventing any internal fluid leakage and compensating any wear of the valve components. However, in this type of valve, since all ports such as the pump port P and the cylinder ports A and B are fixed in its position while the passages 105, 106 and 107 are shifted their positions in response to the shifting movement of the sliding member 108, the valve components assumes the condition somewhat as shown in FIG. 2 during the transition period when the member 108 is shifted from one position to the other. FIG. 2 shows a condition which may be experienced during the shifting movement of the sliding member 108. As shown in FIG. 2, during the transition period, the pump port P or the passage 114P in the balanced piston 112P and the passage 105 are partially opened to valve chamber 103, and the pressurized fluid in the pump port P is allowed to escape to the gap between the port member 101 and the sliding member 108 through the valve chamber 103 and the return bore line to the tank. Therefore, there instantaneously prevails zero pressure in the valve. A similar phenomenon will be seen when the pump port P comes into partial communication with the passage 107. Due to this disadvantageous feature, a valve of this type is limited in its use unless the circuit is specifically designed by incorporating additional components. In other words, if a plurality of valves of this type are connected with a single pump and each of the valves is combined with an actuator so that, by operating the valve, the corresponding actuator can be operated, when one of the valves is shifted from one position in which fluid under pressure is directed to the corresponding actuator, to another position in which fluid under pressure is exhausted from said actuator, fluid pressure in the pump port P of said valve may be allowed to escape into the low pressure line and thus the fluid pressure is lost in the return bore line to the tank. Therefore, the pressure in the other actuators will be simultaneously exhausted through said valve. Thus, by this type of valve, it is very difficult to always maintain the fluid pressure in all of the actuators.

Further, when a plurality of valves such as tandem center type valves are connected in series by connecting the tank port T of the preceding valve with the pump port P of succeeding valve and the oil port of each valve is connected with an actuator, the fluid pressure in the pump port P of the succeeding valve has some influence on the tank port T of the preceding valve. Describing in detail, when the succeeding valve is shifted to the position in which the fluid pressure is supplied to the corresponding actuator, the operating pressure in this actuator increases through the tank port T and the pump port P of the succeeding valve. In this condition, if the valves are of said type, when the preceding valve is operated, the tank port T of the preceding valve is instantaneously allowed to communicate with the valve chamber of the same valve during transition period, so that high pressure fluid is allowed to enter from the tank port into this valve chamber. Therefore, while the valve chamber of the preceding valve is filled with high pressure fluid resulting in the malfunctioning or failure of the valve. For this reason, the valve of said type cannot be used in such a system. Further, in a system having said type of valve, an accumulator, which is intended to charge an excess amount of pressurized fluid so as to provide compensation for the leakage of fluid from the system, is also allowed to discharge the fluid under pressure through the valve during the transition period of the valve. Still further, the valve of this type cannot be used in such a system that gives an inching motion to an actuator due to said disadvantageous feature.

The same disadvantages as possessed by the conventional reciprocating type change-over valve are experienced in a conventional rotary type directional control valve as shown in FIGS. 3 and 4. The illustrated valve is of two position four way type and has a valve body comprising a port member 121 and a casing 123 mounted on the member 121 to form a valve chamber therebetween. The port member 121 is provided with a pump-port P, a tank port T and cylinder ports A and B, and within the valve chamber there is rotatably disposed a rotatable member 122 having four openings for co-operating with the ports formed in the port member. Two of the openings in the rotatable member 122 are connected together as shown in FIG. 3 by a fluid passage 105, and the other two are also connected together by a similar fluid passage (not shown). The rotatable member 122 has a rotatable shaft 124 which is fixed thereon at one end and extends through the casing 123. At the outward end of the shaft 124, there is secured an operating lever 125 so that the rotatable member 122 can be rotated by operating the lever 125 manually. The port member 121 has balanced pistons 112 which are identical in construction to those employed in the reciprocating type valve shown in FIGS. 1 and 2. As in the previously described valve, each of the balanced pistons is urged into a sealing contact with the rotatable member 122 by means of a spring 113 and a pressure difference acting thereon. In this type of valve, since the ports P, A and B are stationary while the passages such as the passage 105 are shiftable, the same problems as in the previously described valve will be encountered during the transition period of the rotatable member 122.

These disadvantages of the conventional valve can be overcome by the novel and improved construction of the present invention as will become clear in the following descriptions with respect to the preferred embodiments shown in the drawings.

Referring now to FIGS. 5, 5a and 6, there is shown a three position four way directional control valve of a sliding plate type. The valve includes a valve body comprising port members 31 and 35 superposed together, a stationary member 33 and a housing 34. Therefore, the valve member 31 is provided with a valve chamber V. Within the valve chamber V, there is disposed a rotatable sliding plate member 22. The port member 35 has a pump port P which is in communication with a suitable fluid pressure source (not shown), a pair of cylinder ports A and B which is adapted to be selectively connected with the pressure port P for directing the fluid under pressure to a selected actuator (not shown), and a tank port T which is in communication with a fluid tank (not shown). The port member 31 is provided with holes 1, 2, 3 and 4 which are in register communication with the ports B, P, A and T respectively. The port member 31, the stationary member 33 and the housing 34 interposed between the members 31 and 33 are fluid tightly assembled with sealing means such as gaskets 29 and form said valve chamber V. The sliding plate member disposed in the valve chamber V is substantially rectangular in shape as shown in FIGS. 6 and 10, and arranged so as to make a face-to-face contact with the upper surface of the port member 31 and the lower surface of the stationary member 33. A rear rod 37 extends through the left end wall of the housing 34 and is connected at its inner end with the left end of the sliding member 22 while its outer end is projected from the left end of the valve body. A front rod 38 which is connected to the left end wall of the housing 34 is connected at its inner end with the right end of the sliding member 22 and at its outer end with a lever 39 for effecting axial movement of the front rod 38. The rear rod 37 is provided with a plurality of recesses which are adapted to be engaged by a detent spring and ball.
assembly 40 so as to hold the sliding member 22 in a selected position. Thus, in this valve, when the lever 39 is manually actuated, the assembly of the front rod 38, the sliding plate 22 and the rear rod 37 is shifted against the action of the detent members 36 so that the means engages with another recess of the rear 37. Therefore, the sliding member 22 and the various members are selectively shown so as to connect the ports P and T with the ports A and B respectively or vice versa.

These arrangements of the valve components are in principle well known in the art, however, according to the present invention, the port member 31, passages and grooves provided in the sliding member 22 and balanced pistons are specially designed so as to prevent fluid leakage, to reduce the leaking resistance, to facilitate the operation of the valve, and to prevent the ports from being simultaneously opened to the tank or any low pressure return line during the transitional period when the sliding member 22 is shifted from one position to another.

According to the present invention, the port member 31 is provided, as shown in FIGS. 7, 8, and 9, on the surface A which contacts with the sliding member 22 a groove b registering to the tank port T and a series of passages 1, 2, and 3 for communication with the port B, P, A and T of the port member 35 respectively as described above. Further, as shown in FIGS. 10 and 11, the sliding member 22 is provided with three stepped passages 11, 12 and 13 comprising three passages of small diameter 5, 6 and 7 and three passages of large diameter 8, 9 and 10. The small diameter passages 5, 6, 7 and 10 open at the side of the sliding member 22 facing to the port member 31, while the large diameter passages 8, 9 and 10 open at the side of the sliding member 22 facing to the stationary member 33. The ports B, P and A, the passages 1, 2 and 3 and the passages 5, 6 and 7 are so arranged that the passages 1, 2 and 3, and thus the ports B, P and A are always maintained in communication with the small diameter passages 5, 6 and 7 respectively in the opposite direction of the position of the sliding member 22. Further, the sliding member 22 is formed with relief grooves 49 and 50 on the side facing to the port member 31. Thus, when the valve is in the neutral position as shown in FIG. 5, the ports P, T, A and B are blocked with each other, however, when it is shifted to the position as shown in FIG. 12, the passage 6 connects the passages 1 and 2, and the relief groove 50 is in communication with the passage 3. Therefore, the pump port P is connected with the port B, while the cylinder port A is connected with the tank port T. On the other hand, when the sliding member 22 is shifted to the extreme right position, the pump port P comes in communication with the port A through the small diameter passage 6 and the port B communicates with the tank port T through the relief groove 49.

Further, in order to provide seal means for preventing the fluid leakage from the gap between the sliding member 22 and the members 31 and 33, the sliding member 22 is constantly urged toward the port member 31 so that they make a face-to-face contact together, and hollow balanced pistons 14, 15 and 16 are disposed in the large diameter passages 8, 9 and 10 respectively with interposition of suitable seal means such as O-rings. The balanced pistons 14, 15 and 16 are constantly urged toward the stationary member 33. When there is fluid pressure prevailing in the passages 1, 2 and 3, the fluid will have a tendency of escaping through the gap between the port member 31 and the sliding member 22, and the fluid pressure in the gap between the members 31 and 22 tends to force the members apart. The pressure receiving areas on which the leaking fluid pressure acts are shown by shadow lines in FIG. 7 and designated by reference letters c, d and e. In the illustrated embodiment, the cross-sectional area of the large diameter passages 8, 9 and 10 are equal to or greater than the area c, d and e so that the sliding member 22 is urged to a fluid tight contact with the port member 31 under the influence of the fluid pressure in the passages 8, 9 and 10. As shown in FIGS. 5 and 12 and as previously described, the balanced pistons 14, 15 and 16, which are in themselves well known in the art and have different effective areas on opposite ends, are disposed in the large diameter passages 8, 9 and 10. The balanced pistons 14, 15 and 16 are pushed into sealing contact with the stationary member 33 by the fluid pressure acting thereon.

Further, in each of the large diameter passages 8, 9 or 10, there is disposed a coil spring 23, 24 or 25 acting between the balanced piston 14, 15 or 16 and the stepped portion 17, 18 or 19 formed between the large diameter passages 8, 9 or 10 and the small diameter passage 5, 6 or 7. Each of the springs 23, 24 and 25 serves to urge the piston 14, 15 or 16 into the fluid tight contact with the stationary member 33, and the sliding member 22 with the port member 31 so as to prevent fluid leakage even when there is sudden increase in pressure in the ports P, A and B which may be experienced for example at the starting period. By this arrangement, the spring force and the fluid pressure serve to prevent fluid leakage between the sliding member 22 and the members 31 and 33.

Since the illustrated valve is constructed as described above, when the sliding member 22 is positioned at the neutral position shown in FIG. 5, all ports are blocked with each other, and when the sliding member 22 is shifted by means of the lever 39 to the position shown in FIG. 12, the pump port P is connected to the cylinder port B and the tank port T is connected to the cylinder port A, while when the member 22 is shifted to the extreme right position, the pump port P is connected to the cylinder port A and the tank port T is connected to the cylinder port B. Thus, by selectively shifting the sliding member 22, the pump port P can be selectively connected to either of the cylinder ports A and B. Further, in this valve, the small diameter passages 5, 6 and 7 are always maintained in communication with the passages 1, 2 and 3 respectively, and the cross-sectional area of the large diameter passages 8, 9 and 10 are equal to or larger than the aforementioned effective area c, d and e, so that the fluid force acting on the area c, d and e and tending to urge the port member 31 and the sliding member 22 apart is overcome by the fluid force acting on the sliding member 22 so that the port member 31 and the sliding member 22 are held together in communication. Moreover, the fluid force is assisted by the spring force obtained through the action of the springs 23, 24 and 25. Further, the balanced pistons 14, 15 and 16 are urged to the stationary member 33 by the fluid pressure difference acting thereon and the said spring action, so that the leakage through the gap between the sliding member 22 and the stationary member 33 is always prevented. It should be noted that, in the illustrated valve, the aforementioned advantages of the conventional valve in that the pump port comes in communication simultaneously with the tank port T via the valve chamber can be effectively eliminated.

Further, in the aforementioned arrangement in which the sliding member 22 is provided with said stepped fluid passages 11, 12 and 13, the amount of force exerted against the sliding member 22 so as to force it toward the port member 31 is determined by the difference between the cross-sectional area of the large diameter passage and the small diameter passage and also by the spring force. Therefore, it is possible to select said area difference and the spring force to a minimum required value so that the valve may be operated with a minimum force even when it is used in an extremely high pressure line. Still further, the illustrated valve is advantageous in that, in addition to the perfect prevention of the fluid leakage through the gaps between the sliding member 22 and members 31 and 33 as described above, the fluid under pressure passing through the valve passes from each of the ports in the port member 31 through only the small diameter passage 6 of the stepped fluid passage 12, and does not pass through any one of the large diameter passages 8, 9 or 10. As shown in FIGS. 5 and 12 and as previously described, the balanced pistons 14, 15 and 16 respectively disposed therein, so that the internal flow resistance can be substantially reduced and thus any efficiency loss due to the internal resistance of the valve can be prevented.

Further, the directional control valve in accordance with the present invention is advantageous over any known spool type directional control valve in that, even when the valve components such as the port member 31, the sliding member
22, the stationary member 33 and the balanced pistons 14, 15 and 16 have worn through the extended usage, since they are so arranged that they are mutually brought into a fluid tight contact by the fluid pressure, any wear on the sliding surfaces can be compensated and does not become unusable as in the case of a spool type valve. Thus, the valve of the present invention is extremely durable, and since all of the sliding surfaces are flat, uniform products of small diameter passage by surface grinding. Accordingly, the valve structure of the present invention is very suitable for mass-production and is effective for obtaining high quality products.

Further, in the aforementioned embodiment, it is very important to note that the valve may be modified in various ways by simply changing the passages, grooves, etc. A few examples of the modifications will now be described.

1. Various types of valve seats may be obtained by slight modifications of the sliding member 22. For example, as shown in FIG. 13, by simply providing a relief groove 26 in the sliding member 22 so as to provide a communication among the ports P, B and A at the neutral position, an all port open type four way control valve (FIG. 13a) may be obtained. Further, as shown in FIG. 14, by providing a communication passage 27 for connecting the relief grooves 49 and 50, a tandem center type four way control valve (FIG. 14a) may be obtained. Similarly, various modifications can be very easily made.

2. The present invention has been described with respect to a directional control valve having a pair of cylinder ports A and B, but the present invention can be embodied in a multiple control valve having a plurality of pairs of cylinder ports A, A', etc. and B, B', etc. Further, the valve in accordance with the present invention may be combined with one or more auxiliary mechanism. For example, a suitable unloading mechanism may be employed and operated with the sliding member 22, or a plurality of suitable load holding mechanism may be arranged in the cylinder ports A and B so as to obtain a plurality of different working pressures.

3. Although the present invention has been described with respect to an example embodied in a reciprocating type control valve, it can be embodied in a valve of rotary type without any inconvenience. Irrespective of whether the valve is of a reciprocating type or a rotary type, it can be designed as either a manual, an electro-solenoid or a solenoid controlled pilot operated type.

4. In the valve described embodiment, the tank port T has been explained as being opened to the tank. However, in the valve according to the present invention, since the ports P, A and B are not opened to the tank, the tank port T may be subjected to a back pressure by only providing a drain port and without necessity of designing as a pressure chamber type. This is one of the most important features of the present invention and will be described later in more detail.

The first embodiment of the present invention has been described above, and it will be clear that in the above described valve the aforementioned problems of the known valve have substantially been overcome. However, it is not a perfect balanced type as explained below. Therefore, it is suitable for a low pressure or medium pressure use rather than a high pressure use. (A valve which is suitable for a high pressure use will be described later as the second embodiment of the present invention.)

In the first embodiment, there will be no problem when the sliding member 22 is in the neutral position. However, when it is shifted for example to the extreme left position as shown in FIG. 15 in which the pump port P is in communication with the cylinder port B through the valve passage of the stepped fluid passage 12 and the cylinder port A is in communication with the tank port T through the relief groove 50, the sliding member 22 will be subjected to upwardly directed fluid forces acting at the center of the ports B, P and A and designated by reference letters R, S and T respectively, and downwardly directed fluid forces acting at the center of the large diameter passages 8, 9 and 10 and designated by the reference letters U, V and W. Since the illustrated valve is an internal drain type, the upwardly directed force T and the downwardly directed force W cancel each other, and as a result, the resultant force F of the upwardly directed forces R and S and the resultant force F of the downwardly directed forces U and V act on the sliding member 22 at different points as shown in FIG. 15. With regard to the moments of the forces F and F about an imaginary point M on the port member 31, unless the product of the resultant force F and the distance between the point M and the point on which the resultant force F acts is larger than that of the resultant force F and the distance between the point M and the point on which the resultant force F acts, the sliding member 22 will have a tendency of departing from the port member 31. Therefore, the resultant force F should be greater than the resultant force F. Thus, the pressures acting on the sliding member 22 are not perfectly balanced. Accordingly, in the above described valve, the sliding member 22 will be disturbed in its free sliding movement as the system pressure increases.

The second embodiment, which will now be described with reference to FIG. 16, is intended to eliminate the above disadvantages encountered in the structure of the first embodiment, and has a movable member comprising a sliding member, said floating member being provided with stepped fluid passages similar to those in the aforementioned structure. By this arrangement, the fluid pressure acting on the movable member is perfectly balanced and thus the movable member will become operable with a small force even when the system pressure is high. Further, in the arrangement, the advantageous features of the above described embodiment are fully retained.

In FIG. 16, there is shown by a longitudinal section a reciprocating type directional control valve embodying the feature of the present invention. In this embodiment, the corresponding parts are designated by essentially the same references as in the previous embodiment. This valve is a four way, all port block, no-spring, three detent position type valve as shown in FIG. 16a, and comprises a valve body including a ported member 31, a stationary member 33 and a housing 34 assembled with interposition of gaskets 36 so as to define a valve chamber V. A port member 35 is mounted on the ported member 31. Within the valve chamber V, there is disposed a rectangular sliding member 22 and a floating member 30, the sliding member 22 being in face-to-face contact at its lower surface with the upper surface of the floating member 30 and at its upper surface with the lower surface of the floating member 30. The floating member 30 is disposed between the sliding member 22 and the stationary member 33 with some clearance in the vertical direction, while it is restricted in longitudinal movement by the housing 34. A rear rod 37 is connected at its inner end to the left end of the sliding member and extends outwardly through the housing 34. An operating lever 39 is pivotally connected to the outer end of the front rod 38 for giving the reciprocating movement thereto. The rear rod 37 is provided with three recesses for engagement with a detent spring and ball means 40. By operating the lever 39, the sliding member 22 is selectively moved against the action of the detent means 40.

As shown in FIGS. 17, 18 and 19, the ported member 31 is formed, on the surface a which is in contact with the sliding member 22, with grooves b communicating through a passage 44 with the tank (not shown). The ported member 31 is further provided with passages 41, 42, 43 and 44 adapted to be connected respectively with the ports B, A and T of the port member 35. The passages are so arranged, irrespective of position of the sliding member 22, the passages 46, 48, and 47 provided in the sliding member 22 (refer to FIG. 20) are always in register with the passages 41, 42 and 43 respectively (FIG. 23). Further, as shown in FIGS. 20 and 21, the passages 46, 47 and 48 pass through the sliding member 22 so that the fluid pressure introduced into the passages 41, 42 and 43 does
not directly act on the sliding member 22 but to the pistons 60, 61, 62 disposed in the large diameter passages formed in the floating member 30. The sliding member 22 is further provided with relief passages 49 and 50 for connecting the tank port T with either the cylinder port A or B.

When the sliding member 22 is in the neutral position as shown in FIG. 16, the ports P, T, A and B are blocked with each other, however, when the sliding member 22 is in the extreme left position as shown in FIG. 23, the passage 48 comes in communication with the passages 41 and 42, and the relief passages 50 connects the passage 47 with the tank groove b so that the communication between the pump port P and the cylinder port B, and that between the cylinder port A and the tank port T are established. Similarly, when the sliding member 22 is in the extreme right position, the ports P and A, and the ports B and T come in communication through the passages 48 and 49 respectively so that the fluid under pressure supplied from the pump (not shown) is introduced through the port P into the port A.

Further, in order to seal the clearance between the port member 31 and the sliding member 22, the floating member 30 is provided with three stepped fluid passages 52, 53 and 54 which are connected from large diameter passages 52A, 53A, and 54A and small diameter passages 52B, 53B and 54B respectively. When a fluid pressure is introduced into the passages 41, 42 and 43, a small amount of fluid under pressure leaks from the clearance between the port member 31 and the sliding member 22 causing them to apart each other. The area on which the leaking fluid pressure acts is somewhat larger than the area of the ports P, B and A and thus that of the passages 41, 42 and 43 as shown by shadow line in FIG. 17. This effective pressure acting area is designated in FIG. 17 by reference characters c, d and e. In the illustrated valve, the area of the large diameter passages 52A, 53A and 54A of said stepped fluid passages 52, 53 and 54 is greater than the area of d, c and e so that the floating member 30 is pushed under the influence of the fluid pressure, toward the sliding member 22 which is in turn urged toward the port member 31. Thus, the clearance between the port member 31 and the sliding member 22 and that between the sliding member 22 and the floating member 30 are effectively sealed. Further, within the large diameter passages 52A, 53A and 54A, there are slidably received pistons 60, 61 and 62 respectively. The pistons 60, 61 and 62 are arranged so as to be directly subjected to the fluid pressure and thus urged toward the stationary member 33. In order to prevent fluid leakage from the clearance between the walls of the passages 52A, 53A and 54A and the pistons 60, 61 and 62, O-rings 52C, 53C and 54C are carried on the peripheries of the pistons. Further, in order to prevent fluid leakage from the clearance between the port member 31 and the sliding member 22 and/or that between the sliding member 22 and the floating member 30 when the ports are so subjected to fluid pressure, or in other words, in order to prevent initial leakage, springs 67, 68 and 69 are disposed within the large diameter passages 52A, 53A and 54A respectively. The springs 67, 68 and 69 act between the pistons 60, 61 and 62 and the stepped portion of the passages, and resiliently urge the pistons 60, 61 and 62 toward the stationary member 33 and thus the port member 30 toward the sliding member 22 which is in turn urged toward the port member 31.

In the valve constructed as described above, all of the ports P, A, B and T are blocked with each other when the sliding member 22 is in the neutral position as shown in FIG. 16, while if the sliding member 22 is shifted to either left or right by operating the lever 39, the ports B and P, and the ports T and A respectively come into communication through the passage 48 and the relief passages 49 and 50 as shown in FIG. 23, or the ports T and B, and the ports P and A come into communication in response to the direction of the movement of the sliding member 22. Further, in the illustrated valve, since the longitudinal position of the floating member 30 remains unchanged relative to the ported member 31 irrespective of the position of the sliding member 22, the working point of the fluid force acting on the effective area c, d, e to cause the ported member 31 and the sliding member 22 to separate each other can be retained in an alignment with the working point of the fluid force acting in the stepped fluid passages 52, 53 and 54, so that the sliding member 22 can be free from such moment that may cause it to be lifted from the ported member 31. Thus, in the illustrated arrangement, a perfect balance of fluid pressure is maintained, and a minimum fluid force which is required for preventing the internal leakage by a suitable selection of the difference between the area of the large diameter passages and said effective area c, d and e. Thus, the valve can be as designed that it can be operated with a light operating force even when it is used in a high pressure system. This manner of design is effective in overcoming the operation difficulty which is often encountered in a conventional valve. Even if the area of the large diameter passages are equal to the area c, d and e described above, a similar advantage may be obtained by suitably selecting the resilient forces of the spring 67, 68 and 69. The sliding member 22 is always urged onto the ported member 31 and the floating member 30 through the action of both the fluid force and the spring force, so that the internal fluid leakage can be substantially prevented.

As will be apparent from the above descriptions, the valve of the second embodiment is essentially a conventional fluid embodiment. The fluid under pressure within the valve flows from the ports in the ported member 31, through the passage 48 and the relief passages 49 and 50, but does not flow through the passages 46 and 47 and the stepped fluid passages 52, 53 and 54 having pistons 60, 61 and 62 received therein, so that the flow resistance within the valve is much smaller than either the conventional valve or the previous embodiment. Moreover, the passage area can be greater than that of the previous embodiment (in FIG. 23, the fluid can pass from the port P to, for example, the port B through the passages 42, 48 and 41 as well as through the passages 42, 48, 52, 48 and 41, while in FIG. 5 it can pass through only one passage), so that efficiency decrease due to the internal flow resistance can be prevented.

Further, in the illustrated valve, any wear of the ported member 31, since the sliding member 22 and/or the floating member 30 may be compensated through the positive contact among the members due to the fluid pressure, the valve will receive little effect from the wear of the valve components and thus the durability of the valve is substantially increased as compared with a spool type valve. Further, since the contact surfaces are all flat, the sliding member 30 will not be stuck in the valve chamber as in the case of a spool type valve. Moreover, all of the contact surfaces can be finished by grinding to obtain products of uniform quality.

In the second embodiment, it should also be important to note that, as in the case of the first embodiment, various modifications can be readily made in simple manners as will now be described.

1. In the preceding description, the sliding member 22 has been explained so as to have the passages 46, 47 and 48 for introducing the fluid pressure into the stepped fluid passages 52, 53 and 54, however, as shown in FIG. 24, the sliding member 32 may be formed without any passage. The type of this valve is shown in FIG. 24a. In such a case, in order to obtain a similar operation, the ports P, B and A may be connected with the stepped fluid passages 52, 53 and 54 through passages separately provided in the valve body (shown by broken lines in FIG. 24) which are led to the portions of the stepped fluid passages above the hollow pistons 60, 61 and 62.

2. Since the above example has been described with respect to an integral type valve in which the valve chamber V is in a integrated communication through the tank port T with the tank (not shown), there has been no stepped fluid passage co-operating to the tank port T, however, the present invention is also applicable to an external drain type valve in which the tank (not shown) is subjected to a block pressure and a drain port D opening to atmosphere is separately provided.
this case, as shown in FIGS. 25 and 25a, the floating member 30 may be provided with stepped fluid passages within which pistons are disposed.

3. Through the above descriptions, the small diameter passage 6 in FIG. 5 or the small diameter passage 48 in FIG. 16 has been explained as the switching passage, but the passages 5, 7, 46 or 47 may be used for this purpose.

4. As a modification of the stepped fluid passage 5e, as shown in FIG. 26, the stepped portion of the passage may not necessarily be floating in the floating member 30’, but may be provided by the surface of the floating member 30’ which is facing to the stationary member 38’ as shown in FIG. 26. The other stepped fluid passages may also be modified in a similar manner.

5. In the above description, only one stepped fluid passage 52, 53 or 54 has been provided for co-operation with each of the ports B, P and A, however, as shown in FIGS. 27 and 28, the passages may be provided in the floating member 30’, but may be divided into two passages 53’ and 53” without any inconveniences. The type of this valve is shown by a symbol in FIG. 27a.

6. The sliding member 22 may be used in various types of valves by simple modifications. For example, as shown in FIGS. 29, 29a, 30, 30a, 31 and 31a, by providing a wide passage under the sliding member 22 so as to establish communication among the ports B, P, A and T or the ports P, A and T at the neutral position, an all port open type four way directional control valve or a partial open center type (B-blocked) four way directional control valve may be obtained, or by providing fluid passages 56 and 57 for connecting the passage 448 with the relief passage 45 and 50 respectively, a tandem center type four way directional control valve may be obtained. Further, by substituting the sliding member 22 by a different type of sliding member, any desired type of valve may be obtained.

7. Since each port may be positively sealed by the sliding member 22 during the transition period thereof, a check device may be provided between two different positions so as to obtain an anching (fine adjustment of fluid flow), shockless, flow control. For example, by providing a cut-off portion H at each port as shown in FIG. 32a, a small amount of fluid flow may be allowed to pass during the transition period. This type of valve is shown symbolically in FIG. 32a.

8. A semi-open center type directional control valve can be obtained by connecting at least two ports at the neutral position so as to allow a restricted flow.

9. Above descriptions are concerned with four way three position type directional control valve, however, the present invention is also applicable to a one-way control valve which has only one discharge port A, B or T or, to a multi-position control valve having more than two discharge ports. Similarly, the present invention is also applicable to a multi-position selector valve in addition to the valves so as to provide a plurality of cylinder ports A, A', ..., and B, B', ..., for obtaining a multiple control feature. Still further, an unloading mechanism may be used with the sliding member 22, or a load holding mechanism may be provided in each of the cylinder ports A and B so as to obtain various working pressure.

10. The above descriptions relate to reciprocating sliding plate type directional control valve, however, the present invention is similarly applicable to a rotary type directional control valve. An example of this type of valve is shown in FIGS. 33, 33a, 34, 35 and 36. In this valve, a stationary member 33’ and the ported member 31’ are assembled together and define a valve chamber V, and a floating member 30’, a rotary sliding member 22’ are disposed within the valve chamber V. The floating member 30’ is provided with stepped fluid passages within which pistons 59’, 60’, 61’ and 62’ are received, and the sliding member 22’ is provided with axial passages 63, 64 and 65. The sliding member 22’ is further provided with a shaft 40 connected thereto at the one end, the other end of the shaft being extending outwardly through the stationary member 33’ and has an operating lever 39’ secured thereto. The sliding member 22’ may be rotated by the operating lever 39’ through the shaft 40 so as to connect the ports together through the passages 63 and 64 or block them with each other. As in the previous examples, the fluid pressure in each port is introduced through either the port 63, 64, 65 or 66 into either one of the stepped fluid passages provided in the floating member and acts on the bottom surface of the piston 60’, 61’, 62’ or 59’ so as to force the piston toward the member 33’ to prevent any fluid leakage. This valve may also be modified as in the case of reciprocal type.

11. The present invention is applicable to any type of valve, such as a hand operated type, an electric-solenoid type, a solenoid controlled pilot operated type, a spring center type, a spring off-set type, a no-spring type, etc. Further, the present invention is applicable to both hydraulic and pneumatic valves.

Claim:

1. In a sliding plate type directional control valve comprising a port member 31 provided with a pump port P and at least one cylinder port B and a tank port T on either side of said pump port, a valve body, said port member and said valve body defining a valve chamber V therebetween, and a sliding member 22 disposed in said valve chamber for sliding movement therein to change the direction of pressure fluid flow from said pump port to said cylinder port through said sliding member 22 without permitting pressure fluid to flow into said valve chamber; the improvement comprising a plurality of stepped fluid passages 11, 12, ..., in said sliding member, each of said stepped fluid passages including a small diameter passage 5, 6, ..., and a large diameter 8, 9, ..., said stepped fluid passages being arranged to continuously communicate with said pump and cylinder ports during sliding movement and in all positions of said sliding member, a plurality of hollow, balanced pistons 14, 15, ..., having opposite end surfaces of different effective area, each of said large diameter passages having one of said pistons disposed therein, each of said pistons being constantly biased toward said valve body, the area of each large diameter passage being greater than the area of the sliding member in communication with the effective pressure receiving areas c, d, ..., of each of said pump and cylinder ports, so that said sliding member is urged toward said port member and held in plane contact therewith, one of said small diameter passages being used to selectively connect said pump port with said cylinder port.

2. A sliding plate type directional control valve in accordance with claim 1, in which a spring 23, 24, ..., is disposed between each balanced piston 14, 15, ... and the stepped portion of each stepped fluid passage formed between the large diameter passage 8, 9, ..., and the small diameter passage 5, 6, ..., the action of the spring and the fluid pressure acting on each large diameter passage 8, 9, ..., being determined to be greater than the fluid pressure acting on the area of the sliding member in communication with the effective pressure receiving areas c, d, ..., of said port member 31.

3. A sliding plate type directional control valve in accordance with claim 2, in which the tank port T is adapted to be subjected to a back pressure, and said sliding member 22 is provided with a stepped passage comprising a large diameter passage and a small diameter passage, a balanced piston which is identical in construction to those defined in claim 2 being disposed within said large diameter passage, a drain port D being provided in the valve chamber V.

4. In a sliding plate type directional control valve comprising a port member 31 having a pump port P and at least one cylinder port B and a tank port T, a valve body, said port member and said valve body defining a valve chamber V therebetween, a sliding member 22 and a floating member 30 disposed within said valve chamber, said sliding member having an upper surface which is in face-to-face contact with said floating member and a lower surface which is in face-to-face contact with said port member, said floating member being
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slightly movable only in a vertical direction, and said sliding member being slidable to change the direction of fluid flow from said pump port to said cylinder port; the improvement comprising a plurality of stepped fluid passages 52, 53 ... in said floating member, each of said stepped fluid passages including a small diameter passage and a large diameter passage, each of said stepped fluid passages being in continuous registered communication with either of said pump or cylinder ports, each of said large diameter passages having a piston 60, 61 ... received in said floating member, the area of each large diameter passage being equal to or greater than the effective pressure receiving area c, d ... of the corresponding port of said port member so that said sliding member may be urged toward said port member, and said floating member may be urged toward said sliding member to hold said sliding member and said port member in plane contact with each other, said sliding member being provided with passages 46, 48 ... for constantly communicating said pump ports with said stepped fluid passages 53 and communicating said cylinder ports with said stepped fluid passages 52 respectively during sliding movement and in all positions of said sliding member, one of said passages 46, 48 ... selectively connecting said pump port with said cylinder port.

5. A sliding plate type directional control valve in accordance with claim 4, in which a spring is disposed between each piston 60, 61 ... and the stepped portion of each stepped fluid passage formed between the large diameter passage 8, 9 ... and the small diameter passage 5, 6 ... , the action of the spring and the fluid pressure acting on each large diameter passage 8, 9 ... being determined to be equal to or greater than the fluid pressure acting on the effective pressure receiving areas c, d ... of the ported member 31.

6. A sliding plate type directional control valve in accordance with claim 5, in which the tank port is adapted to be subjected to a back pressure, and a further stepped flow passage comprising a large diameter passage and a small diameter passage is provided in the floating member 30 for communication with the tank port T, a floating piston received in said large diameter passage, said valve chamber V being provided with a drain port D.