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(54) IMPROVEMENTS IN AND RELATING TO A VALVE ASSEMBLY

(71) We, DANFOSS A/S, a Danish Company, of DK-6430 Nordborg, Denmark, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a valve assembly arrangement for controlling the speed of a hydraulic actuator such as a servo-motor.

The present invention provides a valve assembly for controlling the speed of a hydraulic actuator, the assembly comprising a pressure responsive reducing valve in a return line for the actuator, the reducing valve having a valve member movable in one sense by a spring and in an opposite sense by the pressure of fluid in a pilot line connected to the reducing valve, an adjustable throttle disposed in the return line downstream of the reducing valve, the pilot line being connected to a point in the return line between the reducing valve and the throttle, and another adjustable throttle provided in a supply line for the actuator, the valve member of the reducing valve being movable in the said one sense by the pressure of fluid in another pilot line connected to the reducing valve, the said other pilot line being connected to the supply line at a point between the said other throttle and the load.

In this assembly the reducing valve seeks to keep the pressure constant at the said point in the return line and at a value predetermined by the spring. The quantity of fluid flowing through the return line throttle is therefore dependent only on the orifice cross-section of that throttle. In this way one can, for example, control the lowering speed of a fork lift truck, lift or the like independently of the actual load.

These operating conditions are altered only very little by the fact that, in addition to the spring, the valve member is movable in the said one sense by the pressure of fluid in the said other pilot line. During normal operation, the reducing valve is brought to its open position because the pressure at the said point in the supply line is considerably higher than that at the said point in the return line. If, however, an external load acts on the actuator (for example a servo-motor) in a sense tending to accelerate it, the pressure in the supply line drops and, as a result, the reducing valve takes up a throttling position which prevents excessively rapid outflow of fluid through the return line, and allows the supply line throttle to act as the prime control. If, however, the supply side pressure becomes very low, the pressure at the said point in the return line is reduced to a value governed virtually by the spring alone, so that control of fluid throughflow is effected by the return line throttle. During normal operation, therefore, the control of rate of fluid flow is effected by the supply line throttle and, with a negative load, by the return line throttle, switching over taking place automatically.

It is of particular advantage if a regulating valve is provided which is connected in series with the supply line throttle and which is arranged to hold constant the pressure drop across that throttle. In this way the throughflow of fluid in the supply line is dependent only on the orifice cross-section of the supply line throttle.

Desirably, the reducing valve is so designed that the pressure drop across the return line throttle is at most equal to the pressure drop across the supply line throttle. With such dimensioning, it is ensured that the pressure between the return line throttle and the actuator (servo-motor) will never drop below the tank pressure, i.e. cavitation phenomena are avoided in every case.

It is also favourable if a check valve openable towards the actuator (servo-motor) is connected in parallel with the reducing valve. In this way, the reducing valve will be rendered inoperative if the return line is used as the supply line.

The present invention further provides a valve assembly for controlling the speed of a hydraulic actuator and comprising a fluid flow line for connection to the actuator, a pressure responsive reducing valve connected in the said line, the reducing valve having a valve member movable in one sense by a spring and in an opposite sense by the pressure of fluid in a pilot line connected to the reducing valve, wherein a directional control valve is provided having two operative positions in one of which positions the said fluid flow line acts as a supply line and in the other position of which the said line acts as a return line, two adjustable throttles being provided, one or the other of which is connected in the said fluid flow line when the control valve is in one or other of its operative positions respectively, and the pilot line being connected to a point in the said fluid flow line between the reducing valve and the throttles, the valve member of the reducing valve being movable in the said one sense by the pressure of fluid in another pilot line connected to the reducing valve, the said other pilot line being connected, at least when the said fluid flow line is acting as the supply line, to a point downstream of the throttle in the supply line.

In this case, the pilot pressures will cancel each other out when the fluid flow line is the supply line and the reducing valve will open under the influence only of the spring.

The present invention also provides a valve assembly for controlling the speed of a hydraulic actuator and comprising two fluid flow lines for connection to the actuator, a pressure responsive reducing valve connected in one of the said lines, the reducing valve having a valve member movable in one sense by a spring and in an opposite sense by the pressure of fluid in a pilot line connected to the reducing valve, wherein a directional control valve is provided having two operative positions, in one of which positions the said one fluid flow line acts as a supply line and the other fluid flow line acts as a return line, and in the other position of which the roles of the two fluid flow lines are reversed, and wherein two adjustable throttles are provided, one or other of which is connected in the said fluid flow line when the control valve is in one or other of its operative positions respectively, and the pilot line being connected to a point in the said one fluid flow line between the reducing valve and the throttles, the valve member of the reducing valve being movable in the said one sense by the pressure of fluid in another pilot line connected to the reducing valve, the said other pilot line being connected, when the said one fluid flow line is acting as the supply line, to a point downstream of the throttle in the supply line.

Advantageously, if a negative load can act in both directions of movement of the actuator (motor), e.g. in the case of a control rudder, a further reducing valve may also be provided in the said other fluid flow line and is constructed and arranged to operate in the same way as the aforesaid reducing valve.

Preferably, the orifice cross-sections of the two throttles which are active in one operative position of the control valve are substantially the same as the orifice cross-sections of the other two throttles which are active in the other operative position of the control valve.

In particular, the throttles may be formed in part by the valve member of the directional control valve, which is preferably a two position, four way valve. With such a valve, synchronism of the orifice cross-sections is ensured in a simple manner.

Further, it is advisable if the or each one of the fluid flow lines is provided with a safety valve. This safety valve lowers pressure peaks and therefore not only protects the system but also the series circuit of the reducing valve and the return line throttle.

Valve assemblies constructed in accordance with the invention will now be described, by way of example only, with reference to the accompamying drawings, wherein:—

Figure 1 is a first valve assembly circuit for a single-acting servo-motor;

Figure 2 is a second valve assembly circuit for a double-acting servo-motor in which negative load effects in one direction are controlled; and

Figure 3 shows a modified part of the Figure 3 circuit in which negative load effects in both directions are controlled.

Figure 1 illustrates a single-acting servo-motor 1 with cylinder 2 and telescopic piston 3 of which the connecting conduit 4 is connected by way of a reducing valve 9 to a connection 19 of a three-way switching valve 20 and can be selectively connected by the valve 20 to the pump 6 (operative position *b*) by way of a pressure regulating valve 21 and a throttle path 22 or to a tank conduit 23 (operative position *c*) by way of a throttle path 10.

The valve 9 comprises a valve member in the form of a double-headed spool which is slidably mounted in a cylinder, each head forming with a respective end of the cylinder a respective variable volume chamber one of which is connected to a pilot line 15, which is connected to a point 16 in line 19, and the other of which is connected to a pilot line 17, a spring 18, which is preferably adjustable, being mounted in the chamber connected to pilot line 17. (Figure 3 illustrates a typical form of the valve 9). The pilot line 17 is connected to a conduit 24 which, in the illustrated rest position *a* and in the operative position *c* associated with return flow, is likewise connected to the tank conduit 23 by way of passages 25 but, in the operative position *b* associated with forward flow, is connected to a point 27 downstream of the adjustable throttle in the path 22 by way of a switching path 26. The pressure in the conduit 24 is in addition supplied to the pressure regulating valve 21 in the same sense as the force of a spring 28 whereas in the opposite direction a pressure p_r acts between the regulating valve 21 and the switching valve 20. Further, a safety valve 29 which opens in the usual manner when a predetermined pump pressure is exceeded is connected to the output of the pump 6. A similar safety valve 30 leads from the motor connecting conduit 4 to the tank conduit 23.

The following manner of operation applies to this arrangement. When the switching valve 20 is moved by means of the handle 31 through a predetermined setting path *x* in to the operative position *b*, fluid flows from the pump 6 through the regulating valve 21, the throttling path 22 and the reducing valve 9 to the servo-motor 1. In the conduit 24, and therefore also in the pressure chamber associated with pilot line 17, there is a pressure p_d which also exists in the pressure chamber associated with pilot line 15. The reducing valve 9 therefore opens completely under the influence of the spring 18. The regulating valve 21 is under the influence of the pressure drop at the switching valve 20 and holds this constant. Consequently, the supply quantity and therefore the displacement speed of the servo-motor 1 is determined solely by the orifice cross-section of the throttling path 22, irrespective of the size of the load L. The load can be variable, for example the motor 1 is used in a fork-lift truck. Desirably the regulating valve 21 is designed so that it leads excessive pressure fluid directly to the tank.

If the switching valve 20 is displaced by means of the handle 31 a predetermined setting path *y* to the operative position *c*, then pressure fluid flows from the servo-motor 1 through the reducing valve 9 and the first throttle element 10 to the tank 11. The tank pressure p_t exists in the pressure chamber associated in the line 17 and the pressure p_s exists in the pressure chamber associated with the line 15. Because the reducing valve 9, which was fully open in the rest or closed condition *a* under the influence of the spring 18, is now subjected to the pressure p_s (at the point 16) it is displaced in the closing direction until a pressure as determined by the spring 18 obtains at the point 16. Since the tank pressure p_t is constant, a constant pressure drop $p_s—p_t$ also occurs at the throttle in the path 10. Since these conditions are also substantially maintained on a change in the throttle setting and independently of a change in the load L, the return flow quantity is practically exclusively governed by the set orifice cross-section of the throttle in the path 10. By adjusting that throttle, the lowering movement can therefore be controlled.

In the arrangement according to Figure 2, a servo-motor 32 is provided which comprises a cylinder 33 and a piston 34 that can be loaded by an external load L. Accordingly, two motor connecting conduits 35 and 36 are also provided which communicate with the tank conduit 23 through a safety valve 37 and 38. For the purpose of replenishment, the connecting conduit 36 is connected to the tank conduit 23 by a check valve 39. The connecting conduit 35 communicates with a connection 40 through the reducing valve 9 and the connecting conduit 26 communicates directly with a connection 41 of a four-way switching valve 42 which is adjustable by a handle 43. For each operating direction there is a first throttle element 10 or 10′ for the return flow and a second throttle element 44 or 44′ for the forward flow. No throttle elements are adjustable in unison. For the operative position *b* (setting path *x*) and the operative position *c* (setting path *y*) they have the same orifice cross-section in pairs. In other particulars, the circuit corresponds to Figure 1.

The manner of operation is in this case as follows. When the switching valve 42 is displaced through a setting path x into the operative position b, pressure fluid flows from the pump 6 through the regulating valve 21, the second throttle element 44′ and the reducing valve 9 to the left-hand side of the servo-motor 32. At the same time, pressure medium flows through the first throttle element 10′ to the tank. The pressure p_d is applied to the conduit 17 through the switching path 26. Accordingly, the reducing valve 9 is opened fully by the desired value spring 18. The regulating valve 21 holds the pressure drop at the switching valve 42 constant. The arriving quantity is therefore determined by the setting path *x* and the corresponding throttle orifice in the throttle element 44′.

If the switching valve 42 is displaced to the operative position *c* through a setting path *y*, arriving pressure fluid flows through the throttle element 44 direct to the right-hand side of the servo-motor 32. Simultaneously, the pressure chamber associated with line 17 of the reducing valve 9 is again supplied with the pressure p_d, whilst the pressure p_s at the point 16 is regulated by the reducing valve 9. The returning quantity of pressure fluid flows through the now regulated reducing valve 9 and then through the settable throttle element 10. When no negative load L is present, the pressure p_d in the pressure chamber associated with line 17 is considerably higher than the pressure p_s in the pressure chamber associated with line 15, so that the reducing valve 9 is completely open and the control of the operating quantity is effected solely by the throttle element 44. If, however, the negative load L becomes larger, the pressure p_d drops until the pressure p_s finally becomes so large that the reducing valve 9 is moved in the closing direction. This results in throttling of the quantity of return flow, so that the control operation for the supply conduit can still be maintained. If, however, the pressure in the connecting conduit 36 becomes so low by reason of the negative load L that control on the supply side is no longer possible, the pressure in the pressure chamber associated with line 17 is likewise so low that the pressure p_s can be kept constant by the reducing valve 9 and the control of the throughflow quantity is now effected by the throttle element 10.

The following numerical example will make the manner of operation still clearer. It is assumed that the pressure drop over the throttle element 44 or 44′ is kept constant at 4 bar by means of the regulating valve 21, that the load L=200 bar, that the cross-section of the cylinder on the left-hand side is twice that on the right-hand side, that the desired value spring 18 exerts a pressure of 3 bar, and that the throttle elements 10, 44 or 10′, 44′ have the same orifice in pairs. Further, the setting is to be such that 5 litres flow through the throttle element 44′.

a) If the switching valve 42 is displaced to the operative position *b*, the pressure drop at the throttle element 10 can be calculated to be 1 bar. When the tank pressure is 0 bar, the pressure p_s is 201 bar and the pump pressure 204 bar.

b) If the switching valve 42 is displaced to the operative position *c*, the pressure drop at the throttle element 10 can be calculated to be 16 bar. Since this pressure is equal to the pressure p_d in the supply conduit plus a constant pressure emanating from the spring 18, this pressure p_d amounts to 13 bar and consequently the pump pressure p_p amounts to 17 bar.

In the arrangement according to Figure 3, only the part of the circuit disposed beyond the switching valve 42 is illustrated. This time both connecting conduits 35 and 36 are connected to the associated connections 40 and 41 by way of a respective reducing valve 9 or 9′. Both are bridged by a check valve 45, 45′ that opens towards the motor 32. The pressure chamber 15 communicates with the point 16 and the pressure chamber 15′ with the point 16′. The pressure chamber 17 communicates with a point 46 at the connection 41 or at the connecting conduit 36 and the pressure chamber 17′ communicates with a point 46 at the connection 40 or at the connecting conduit 35.

When the connection 41 transmits supply pressure, the servo-motor 32 is fed by way of the check valve 45′. The reducing valve 9 goes over the open position so that the pressure fluid can flow off without hindrance. Only when the load L is too large and the pressure in the connection 41 drops will the reducing valve have a throttling effect in the described manner. The same also applies to adjustment of the motor 32 in the reverse direction with a correspondingly reversely acting external load.

Instead of the check valves 45, 45′ one can also use reducing valves 9, 9′ controlled in the nature of the reducing valve 9 of Figure 2 by way of the switching valve 42.

WHAT WE CLAIM IS:—

1. A valve assembly for controlling the speed of a hydraulic actuator, the assembly comprising a pressure responsive reducing valve in a return line for the actuator, the reducing valve having a valve member movable in one sense by a spring and in an opposite sense by the pressure of fluid in a pilot line connected to the reducing valve, an adjustable throttle disposed in the return line downstream of the reducing valve, the pilot line being connected to a point in the return line between the reducing valve and the throttle, and another adjustable throttle provided in a supply line for the actuator, the valve member of the reducing valve being movable in the said one sense by the pressure of fluid in another pilot line connected to the reducing valve, the said other pilot line being connected to the supply line at a point between the said other throttle and the actuator.

2. An assembly as claimed in Claim 1, in which a regulating valve is provided which is in series with the said other throttle and which is arranged to hold constant the pressure drop across the said other throttle.

3. An assembly as claimed in Claim 2, in which the reducing valve is so designed that the pressure drop across the return line throttle is at most equal to the pressure drop across the said other throttle.

4. An assembly as claimed in any one of Claims 1 to 3, in which a check valve openable towards the actuator is connected in parallel with the reducing valve.

5. A valve assembly for controlling the speed of a hydraulic actuator and

comprising a fluid flow line for connection to the actuator, a pressure responsive reducing valve connected in the said line, the reducing valve having a valve member movable in one sense by a spring and in an opposite sense by the pressure of fluid in a pilot line connected to the reducing valve, wherein a directional control valve is provided having two operative positions in one of which positions the said fluid flow line acts as a supply line and in the other position of which the said line acts as a return line, two adjustable throttles being provided, one or the other of which is connected in the said fluid flow line when the control valve is in one or other of its operative positions respectively, and the pilot line being connected to a point in the said fluid flow line between the reducing valve and the throttles, the valve member of the reducing valve being movable in the said one sense by the pressure of fluid in another pilot line connected to the reducing valve, the said other pilot line being connected, at least when the said fluid flow line is acting as the supply line, to a point downstream of the throttle in the supply line.

6. A valve assembly for controlling the speed of a hydraulic actuator and comprising two fluid flow lines for connection to the actuator, a pressure responsive reducing valve connected in one of the said lines, the reducing valve having a valve member movable in one sense by a spring and in an opposite sense by the pressure of fluid in a pilot line connected to the reducing valve, wherein a directional control valve is provided having two operative positions, in one of which positions the said one fluid flow line acts as a supply line and the other fluid flow line acts as a return line, and in the other position of which the roles of the two fluid flow lines are reversed, and wherein two adjustable throttles are provided, one or other of which is connected in the said fluid flow line when the control valve is in one or other of its operative positions respectively, and the pilot line being connected to a point in the said one fluid flow line between the reducing valve and the throttles, the valve member of the reducing valve being movable in the said one sense by the pressure of fluid in another pilot line connected to the reducing valve, the said other pilot line being connected, when the said one fluid flow line is acting as the supply line, to a point downstream of the throttle in the supply line.

7. An assembly as claimed in Claim 6, in which two further throttles are provided, one or other of which throttles is connected in the said other fluid flow line when the control valve is in one or other of its operative positions respectively, the said other pilot line being connected, when the said other fluid flow line is acting as the supply line, to a point downstream of the further throttle in the supply line.

8. An assembly as claimed in Claim 6 or Claim 7, in which a further pressure responsive reducing valve is provided in the said other fluid flow line and is constructed and arranged to operate in the same way as the aforesaid reducing valve.

9. An assembly as claimed in Claim 7 or Claim 8, in which the orifice cross-sections of the two throttles which are active in one operative position of the control valve are substantially the same as the orifice cross-sections of the other two throttles which are active in the other operative position of the control valve.

10. An assembly as claimed in any one of Claims 5 to 9, in which the throttles are formed in part by the valve member of the directional control valve.

11. An assembly as claimed in Claim 10, in which the directional control valve is a two position, four way valve.

12. An assembly as claimed in any one of Claims 5 to 11, in which the or each one of the fluid flow lines is provided with a safety valve.

13. A valve assembly for controlling the speed of a hydraulic actuator, the assembly being substantially as hereinbefore described with reference to and as illustrated by the accompanying drawings.

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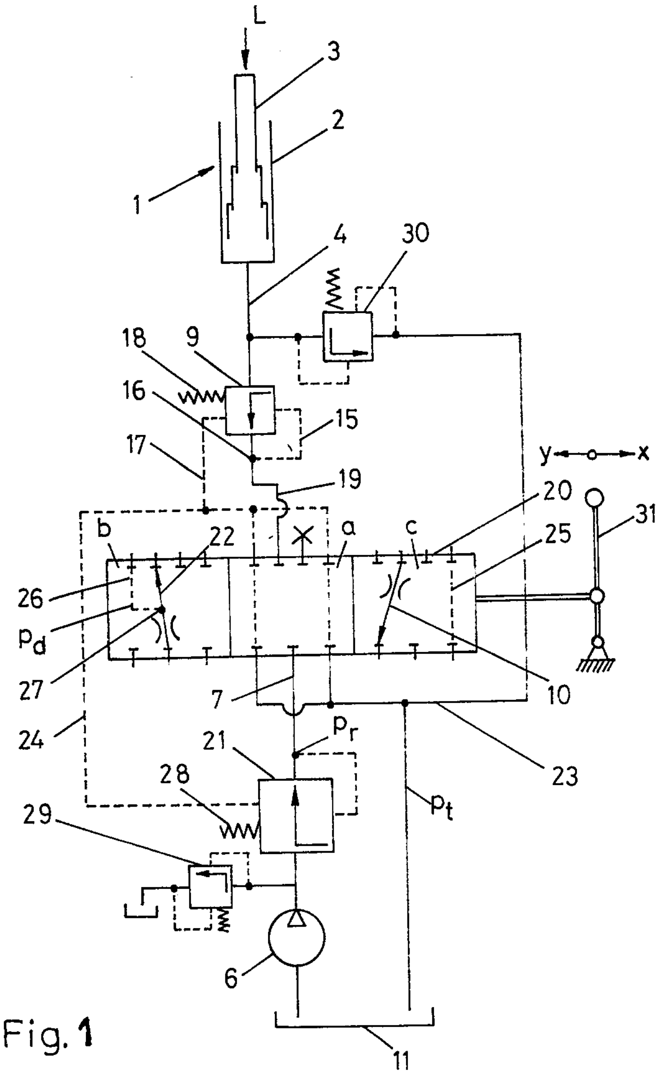
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Fig. 1

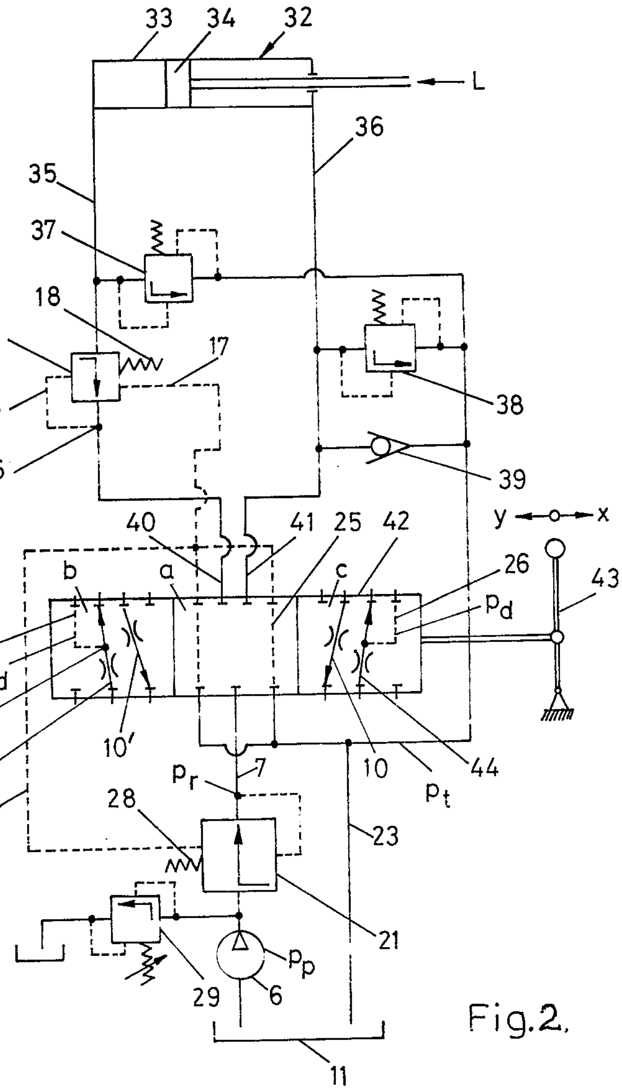
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Fig.2.

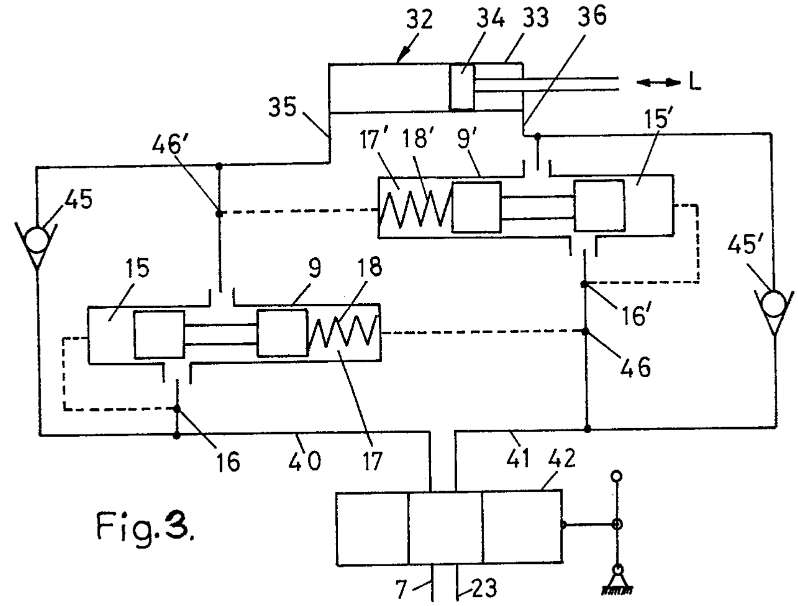

Fig. 3.