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(54) **Hydraulic control circuit for an hydraulic ram.**

(57) An hydraulic control circuit for the hydraulic rams (1) of the boom of an excavator includes a servo-controlled hydraulic selector valve (14) for selectively connecting a source of hydraulic pressure (12, 13) to the rams for raising or lowering the boom. Load control valves (4) connected to the raising sides of the rams include pilot-operated relief valves (7) for controlling the outlet of hydraulic fluid from the rams during lowering of the boom. In order to provide for a fast rate of descent of the boom, when required, the relief valves (7) are controlled by an hydraulic intensifier (11*a*) which is responsive to operation of the servo hand controller (16) upon lowering of the boom. The hydraulic pressure signal from the appropriate line (15) connecting the servo controller to the selector valve (14) is applied to the input (24) of the hydraulic intensifier, upon selection of the lowering mode, and its output signal is fed to the pilot lines (10) of the relief valves (7).

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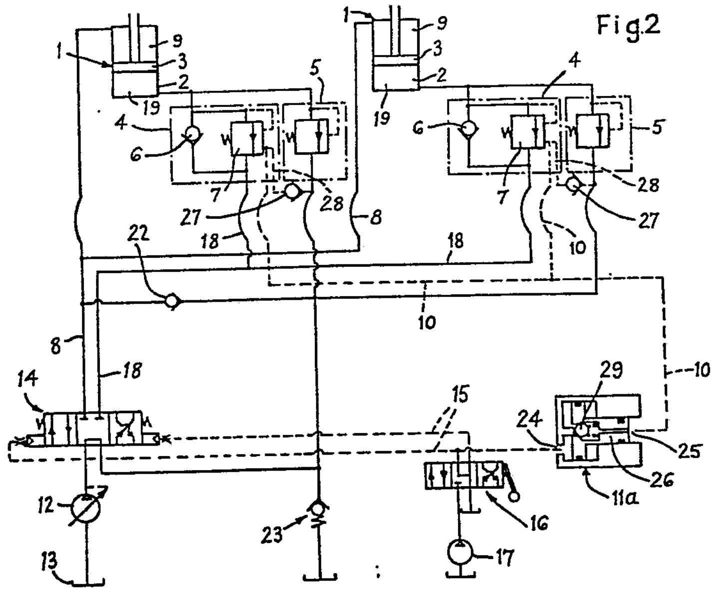

Fig.2

HYDRAULIC CONTROL CIRCUIT FOR AN HYDRAULIC RAM

This invention relates to a hydraulic control circuit for a hydraulic ram (cylinder + piston) controlling raising and lowering of a mechanical member, more particularly but not exclusively for ram cylinder control of the boom of a hydraulic excavator.

Where hydraulic excavators are used in situations such that men may be working in close proximity to the machine boom and bucket, such as when the excavator is used for craning operations, lowering pipes, shuttering etc., it is highly desirable, and is likely to be mandatory in the future, that the boom should be prevented from sudden uncontrollable lowering in the event of an hydraulic system failure, such as a hose break, by the incorporation of some form of load control valve in the hydraulic circuit. Similarly, in such situations, accurate control and positioning of the load becomes of utmost importance.

It is known to incorporate over-centre valves in such hydraulic control circuits, which valves react quickly, have good control, a low level of leakage, and protect the structure and ram cylinders from the effects of transient pressure which could occur when stopping downward movement of the boom. Essentially, the over-centre valve is a pilot operated relief valve and is mounted on a ram cylinder. The pilot pressure used to control the valve is obtained from the feed line to the lowering side of the boom cylinders. With this arrangement, the boom may not lower at a faster rate than that determined by the flow of oil into the lowering side of the ram cylinder, since any tendancy to over-run the pump flow will cause the feed line pressure, and hence the over-centre valve pilot pressure, to fall leading to closing of the valve. This feature, while giving good control after a hose break in the feed line supplying the full area of the ram cylinder, unduly restricts the lowering speed of the boom.

This is a disadvantage since it is common practice for the boom of an hydraulic excavator to be lowered at a speed faster than would be determined by the flow of oil into the lowering side of the boom cylinder, the deficiency of flow being made up from a low pressure source through a non-return valve. A fast rate of descent of the boom is required since, during a typical digging cycle in which earth is dug from beneath the ground level and dumped above, the lowering of the boom into the hole is essentially a non-productive part of the operation and, as such, should be executed rapidly, consistent with machine stability.

An object of the present invention is to overcome or substantially reduce the abovementioned disadvantage.

To this end, the present invention consists in an hydraulic control circuit for a hydraulic ram controlling raising and lowering of a mechanical member, comprising a source of hydraulic pressure, a selector valve for selectively connecting the hydraulic source to opposite sides of the ram whereby actuation of the selector valve operates the ram to raise or lower the mechanical member, a load control valve disposed adjacent to the ram and connected between the raising side of the ram and the selector valve, said load control valve comprising non-return valve means via which hydraulic pressure is applied to the raising side of the ram and hydraulically operated relief valve means for controlling the outlet of hydraulic fluid from said raising side when applying hydraulic fluid pressure to the lowering side and means responsive to a predetermined hydraulic fluid pressure or flow applied to the lowering side for supplying hydraulic fluid pressure to operate the relief valve means at a sufficient pressure to retain the relief valve means open as the lowering speed increases above that determined by the supply of hydraulic fluid pressure to the lowering side.

In hydraulic circuits constructed in accordance with the invention for boom ram control, the boom is either locked and prevented from falling after a hose burst or continues the selected movement in a controllable manner depending upon which hose bursts, the maximum speed of lowering of the boom under normal conditions is controlled at a speed faster than would be determined by the flow of oil into the lowering side of the ram cylinder, and boom drift, i.e. lowering of the boom due to any leakage in the system, is prevented by the load control valve.

In order that the invention may be more readily understood, embodiments thereof will now be described, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 shows, diagrammatically, one embodiment of hydraulic control circuit for hydraulic rams controlling raising and lowering of the boom of an hydraulic excavator,

Figures 2 and 3 show, diagrammatically, two other embodiments respectively, and

Figure 4 is a cross-section of one form of load-control valve suitable for incorporation in the circuit of Figure 3.

In the drawings like reference characters are used to designate the same or similar parts.

The circuit shown in Figure 1 is used to control two hydraulic excavator boom rams 1 each comprising a respective cylinder 2 and piston 3. Although two rams 1 have been shown, one larger ram may alternatively be used. The circuit incorporates, for each ram 1, a load control valve 4 with a respective separate ram cylinder relief valve 5 and associated hydraulic lines and connections which are the same in each case. Thus, for simplicity, one ram only will be referred to as if there is only one ram and its associated load control valve 4, relief valve 5 and connecting lines in the hydraulic circuit. The load control valve 4 has good metering characteristics i.e. progressive opening in response to pilot operating pressure, and comprises a non-return valve 6 and a pilot operated relief valve 7. The valve pilot pressure used to control the opening of the load control valve 4 i.e. the relief valve 7 is obtained from a boom lowering feed line 8 connected to the lowering side 9 of the ram cylinder 2, via a pilot line 10. A sequence valve 11 is located in the lowering feed line 8 between the point where valve pilot pressure is taken off through line 10 and the lowering side 9 of the ram cylinder.

A main hydraulic pump 12 with reservoir 13 is connected to a selector valve 14 having a directional flow control function which controls the main pump flow through the circuit and which, itself, is controlled remotely via control lines 15 by a servo hand controller 16 with its own pump 17. When the selector valve 14 is operated to raise the boom, fluid flows along a feed line 18 to the raising side 19 of the ram cylinder via the non-return valve 6 with minimal restriction on flow. Return flow from the cylinder lowering side 9 will also pass with minimal restriction through a non-return valve 20 connected to feed line 8 in parallel with the sequence valve 11. Thus, the load control valve 4 and the sequence valve 11 have little effect on the raising of the boom. Should a hose break occur in the feed line 18 to the cylinder raising side 19, the non-return valve 6 ensures that the boom cannot suddenly fall.

When the selector valve 14 is operated to lower the boom, pressure is raised in the boom lowering feed line 8 due to the relief valve 7 of the load control valve 4 remaining closed initially. This pressure is also applied to the pilot line 10 causing the relief valve 7 to open, this being identical in operation to that of the normal over-center valve previously described. However, in Figure 1, when the servo-hand controller is fully selected to boom lower to obtain a high rate of descent, the pump flow through an orifice 21 connected in parallel with the sequence valve 11 and non-return valve 20 creates a pressure drop across the orifice sufficient for the relief valve 7 of the load control valve 4 to be piloted fully open from the upstream side of the orifice 21 and ensure that relief valve remains fully open as the boom lowering speed is increased above that determined by the pump flow into the cylinder lowering side 9, while the downstream pressure at the ram cylinder 2 falls low enough to permit flow from a make-up non-return valve 22 to supplement the orifice flow to make up any flow deficiency in the cylinder lowering side 9. The make-up valve 22 is fed off a low pressure gallery by pump flow returning from the selector valve, the pressure of which is controlled by a make-up gallery relief valve 23. This ensures that cavitation does not occur within the ram cylinder 2.

At lower rates of boom descent, i.e. when the flow of fluid into the lowering feed line 8 is metered by the selector valve 14, the pressure drop across the orifice 21 will not be sufficient for the relief valve 7 to be piloted fully open. This will result in restriction of flow from the ram cylinder 2 through the relief valve 7 such that the pressure in the boom lowering line 8 will increase. This increase will prevent any make-up flow through the valve 22 supplementing the pump flow into the cylinder lowering side 9. Thus, the lowering of the boom will be controlled by the load control valve 4 in response to the metered flow in feed line 8. It will be evident that, under these conditions, the failure of a hose in the boom raising line 18 will have a negligible effect on this control.

The purpose of the sequence valve 11 in parallel with the orifice 21 is to limit the maximum level of pressure at the upstream side of the orifice 21 as a protection for the pipe work and load control valve 4. Since the non-return valve 20 is also in parallel there is unimpeded return flow from the cylinder 2 when boom raise is selected.

In the event of sudden arrest of lowering of the boom, the separate ram cylinder mounted relief valve 5 ensures that transient pressures within the ram cylinder 2 are limited in magnitude, thus giving protection to the structure. Alternatively, the load control valve 4 could provide this feature when used with a selector valve having an open centre spool, (the selector valve 14, has a closed centre spool necessitating the inclusion of the relief valve 5 for operational reasons).

Whilst the circuit of Figure 1 operates satisfactorily, it has been found that in order to obtain a reasonably high speed of descent, the sequence valve setting is necessarily of the order of 2,500 psi. This can cause power loss in the hydraulic system with heat build-up and, when using power compensated pumps, can result in reduction in flow with consequent slowing of other system functions which may be operated simultaneously with the lowering of the boom.

The circuits of Figs. 2 and 3 avoid these possible problems.

Referring now to Fig. 2, this differs from Fig. 1 in that the sequence valve 11, non-return valve 20 and orifice 21 are replaced by a hydraulic intensifier 11a. In this embodiment, advantage is taken of the pressure signal from the servo-hand controller 16 for remotely activating the selector valve 14 to cause lowering of the excavator boom by feeding this pressure signal from the appropriate line 15 into the input 24 of the hydraulic intensifier 11a. The output signal from the hydraulic intensifier is fed at its output 25 to the pilot line 10 for the relief valve 7 of the load control valve 4. By this means, sufficient pilot pressure is obtained to give an acceptable boom lowering speed whilst using a low-pressure energy source.

The pilot line 10 from the intensifier 11a to the body of the load control valve 4 would normally be a closed line in which entrained air would not be flushed out. This could critically effect the operation of the relief valve 7 since, if sufficient in quantity, the amount of compression required would exceed the available displacement of the intensifier output piston 26. Thus, to guard against this occuring, the circuit includes an automatic bleed system operative when boom lowering is not selected, to flush the pilot line 10 from the load control valve body and through the intensifier 11a. This bleed system includes a non-return valve 27 and line 28 connected into the pilot port of the relief valve 7 and a non-return valve 29 in the intensifier 11a which is unseated when the intensifier is inoperative, such that flow will be induced in the pilot line 10 from the relief valve to the intensifier, thus purging the lines and cavities within the relief valve pilot section and the intensifier.

It will be appreciated from Fig. 2, that the point where the line 28 connects into the pilot line 10 is inside the body of the load control valve. This ensures that the bleed flow which exists when boom lower is not selected enters the load control valve body by one port and leaves by another port, thus purging the body cavity of any air.

Referring now to Figures 3 and 4, the circuit of Figure 3 differs from that of Figure 1 in that the sequence valve 11, valve 20 and orifice 21 are omitted and a venting valve 30 is incorporated in a pilot line 31 connected to a port 32 in the relief valve 7 and to the servo-hand controller 16 and one of the lines 15. The load-control valve 4 consists of the relief valve 7 and non-return valve 6 which are independent of each other but which are contained within a common valve body 33. The relief valve 7 has a hollow-cylindrical valve plunger 34 which is slidingly and sealingly mounted within the valve body 33, the annular seals 35 dividing the valve body into four chambers 36, 37, 38 and 39 which are connected respectively through ports 40, 41, 42 and 32 to the raising side 19 of the ram cylinder 2, the raising feed line 18 to the selector valve 14, the pilot line 10 connected to the lowering feed line 8, and the pilot line 31 to the vent valve 30. The left-hand end of the valve plunger 34 is normally biased into a position in which it engages a valve seat 43 on the valve body 33 by means of a compression spring 44 in the valve chamber 39 and acting between the opposite end of the valve body and valve plunger.

The action of pressure due to the loaded ram cylinder 2 acting on a small annular area 45 defined by the outside diameter of the valve plunger 34 and the mating seat engaging diameter of the plunger end disengages the plunger end from its seat 43 against the action of the spring 44 to open valve 7. This action is aided by the application of a pilot pressure through line 10 and port 42 to a further annular area 46 which generally is of larger area than the area 45 acted on by the cylinder load pressure. Disengagement of the cylinder end from the valve seat 43 allows flow from the loaded cylinder through the valve body, the port 41 and line 18 to the selector valve 14. Since back pressure in the port 41 will act on anarea defined by the diameter of the left-hand plunger end, balancing holes 47 are provided through the plunger 34 to feed this pressure into the spring chamber 39 and thus balance the effects of back pressure on the plunger. By venting the pressure within the spring chamber 39 to drain, the back pressure can be used to fully open the valve (disengagement of plunger from valve seat 43), allowing minimum restriction to the flow out of the cylinder 2 through the port 32. The balancing holes 47 must be carefully selected to ensure that the venting valve 30 may be quite small. This valve 30 is set to ensure that only when the servo signal to the selector valve 14 has reached a certain level, predetermined by tests, will the valve 30 open to vent the spring chamber 39 and thus fully open the relief valve 7. This ensures that the relief valve offers a minimum of resistance to the flow of fluid from the cylinder with no extra energy consumption imposed on the circuit. Thus, the relief valve 7 is maintained fully open to provide acceptable boom lowering speed rates when boom lower is fully selected by the servo-hand controller 16.

The non-return valve 6 comprises a valve plunger 47a which is urged into engagement at one of its ends with a mating seat 48 on the valve body 33 by a spring 49 disposed in a chamber 50. Passages 51, and 52 in the valve body communicate with the port 40 to the raising side of the ram cylinder 2, with the spring chamber 50 and an annular chamber 53 adjacent the valve seat 48 respectively. Thus, when the selector valve is operated to boom raise, pump flow through port 41 is connected to raising feed line 18 and the interior of valve plunger 34 causes the valve plunger 47a to be moved to the left as illustrated in Fig. 4 disengaging the latter from its seat and opening the valve 6 against the spring pressure so that flow passes through valve chamber 48 and passage 52 to port 40. Any hose burst in the feed raising line 18 will result in the valve plunger 47a immediately re-engaging the seat

48 and thus closing the non-return valve 6.

An additional feature of the circuit described with reference to Figure 3 is that since at low servo pressures the venting valve 30 is inoperative, then after a hose failure in the boom raising feed line 18, the lowering of the boom remains under the control of the pump flow since, any tendancy to run-away, leads to loss of pressure within the lowering feed line 8 and hence in the pilot line 10, causing the relief valve 7 to shut. Thus, under these conditions, the circuit operates as described previously for the over-centre valve.

Although particular embodiments have been described with reference to boom control ram cylinders, it should be appreciated that the invention is also applicable to the control of the ram cylinders of other mechanical members, such as bucket arm and handle control cylinders and wrist control cylinders.

CLAIMS

1. An hydraulic control circuit for an hydraulic ram (1) controlling raising and lowering of a mechanical member, characterised by a selector valve (14) for selectively connecting a source of hydraulic fluid pressure to opposite sides of the ram, whereby actuation of the selector valve operates the ram to raise or lower the mechanical member, a load control valve (4) connected between the raising side (19) of the ram and the selector valve (14), said load control valve comprising non-return valve means (6), via which hydraulic pressure is applied to the raising side of the ram, and pilot-operated relief valve means (7) for controlling discharge of hydraulic fluid from the raising side of the ram in response to application of hydraulic fluid pressure to the lowering side (9) thereof, and means (21,11a,30) for retaining the relief valve means (7) open as the lowering speed of the ram increases above the maximum speed determined by the available hydraulic fluid supply.

2. An hydraulic circuit as claimed in claim 1, characterised in that the relief valve means (7) is hydraulically actuated and has a pilot line (10) connected to the lowering side (9) of the ram, and the means (20,21) for retaining the relief valve means open is disposed between the connection of said pilot line (10) and the lowering side (9) of the ram and is adapted to constrict flow of hydraulic fluid to said ram upon lowering movement thereof, thereby to maintain at least a predetermined minimum hydraulic pressure applied to the pilot line (10) so as to maintain the relief valve means open, whilst permitting unrestricted discharge of hydraulic fluid from said ram upon raising movement of the latter.

3. An hydraulic circuit as claimed in claim 2, characterised in that the means for retaining the relief valve means (7) open comprises a flow restricting

orifice (21) connected in parallel with a non-return valve (20) permitting unrestricted discharge of fluid from the ram.

4. An hydraulic circuit as claimed in claim 2 or 3, characterised in that the means for retaining the relief valve means (7) open includes valve means (11) for limiting the hydraulic pressure on the side of said retaining means (20,21) remote from the ram to a predetermined maximum.

5. An hydraulic circuit as claimed in claim 1, characterised in that the selector valve (14) is hydraulically actuated and is remotely controlled by a servo selector valve (16), the relief valve means (7) is hydraulically actuated, and the means for retaining the relief valve means open comprises hydraulic intensifier means (11<u>a</u>) which is responsive to actuation of the servo selector valve (16) to lower the ram so as to apply hydraulic pressure to the pilot circuit (10) of the relief valve means.

6. An hydraulic circuit as claimed in claim 5, characterised by purging means (27,28) for automatically flushing the pilot circuit of the relief valve means (7) and the intensified means (11<u>a</u>) when lowering movement of the ram is not selected.

7. An hydraulic circuit as claimed in claim 1, characterised in that the relief valve means (7) is hydraulically actuated and has a pilot line (10) connected to the lowering side (9) of the ram, the relief valve means including a valve member (34) moveable to connect an inlet port (40) of the relief valve means to an outlet port (41) and permit discharge of hydraulic fluid from the raising side (19) of the ram, whereby an hydraulic back pressure is applied to one side of said valve member, and means (47) for applying said back pressure to the opposite side of said valve

member to balance the effect of said back pressure thereon, and further characterised in that said means for retaining the relief valve means open comprises venting valve means (30) connected to said opposite side of said valve member to vent hydraulic fluid pressure therefrom in response to actuation of the selector valve (14) to maximise the lowering speed of the ram, whereby said back pressure retains said relief valve means open.

8. An hydraulic circuit as claimed in claim 7, characterised in that the selector valve (14) is hydraulically actuated and is remotely controlled by a servo selector valve (16), and the vent valve means (30) is hydraulically actuated and is responsive to actuation of the servo selector valve (16) to maximise the lowering speed of the ram.

9. An hydraulic circuit as claimed in any one of the preceding claims, characterised by means (22) for supplying make-up hydraulic fluid to the lowering side (9) of the ram in response to the decrease below a predetermined minimum pressure of the hydraulic pressure applied to said lowering side.

10. An hydraulic circuit as claimed in any one of the preceding claims, including pilot-operated relief valve means (5) connected in parallel with said load control valve (4) and responsive to the hydraulic pressure at the raising side (19) of the ram for limiting the hydraulic pressure of the raising side to a predetermined maximum, whereby to protect the circuit against overload pressure.

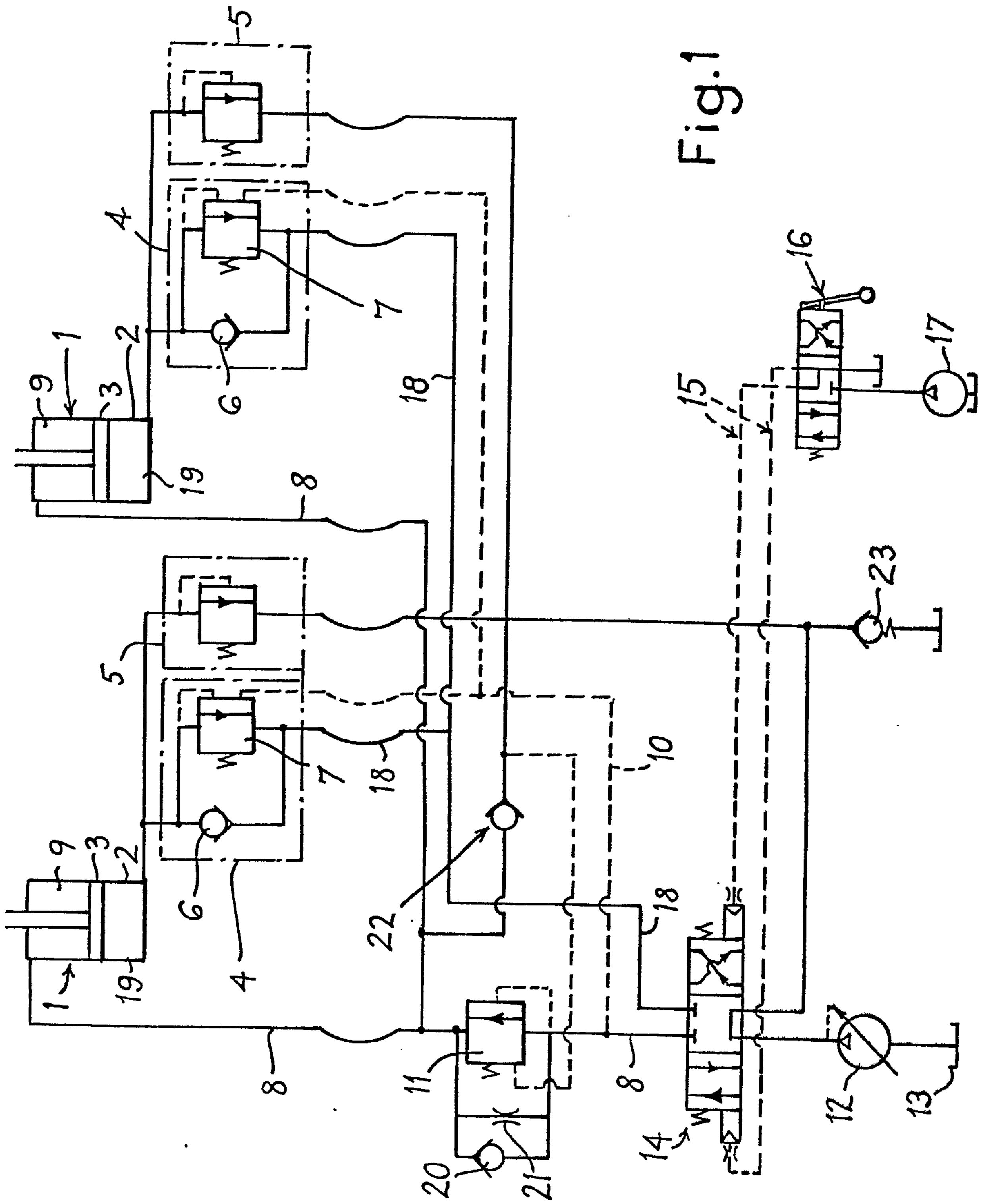

Fig.1

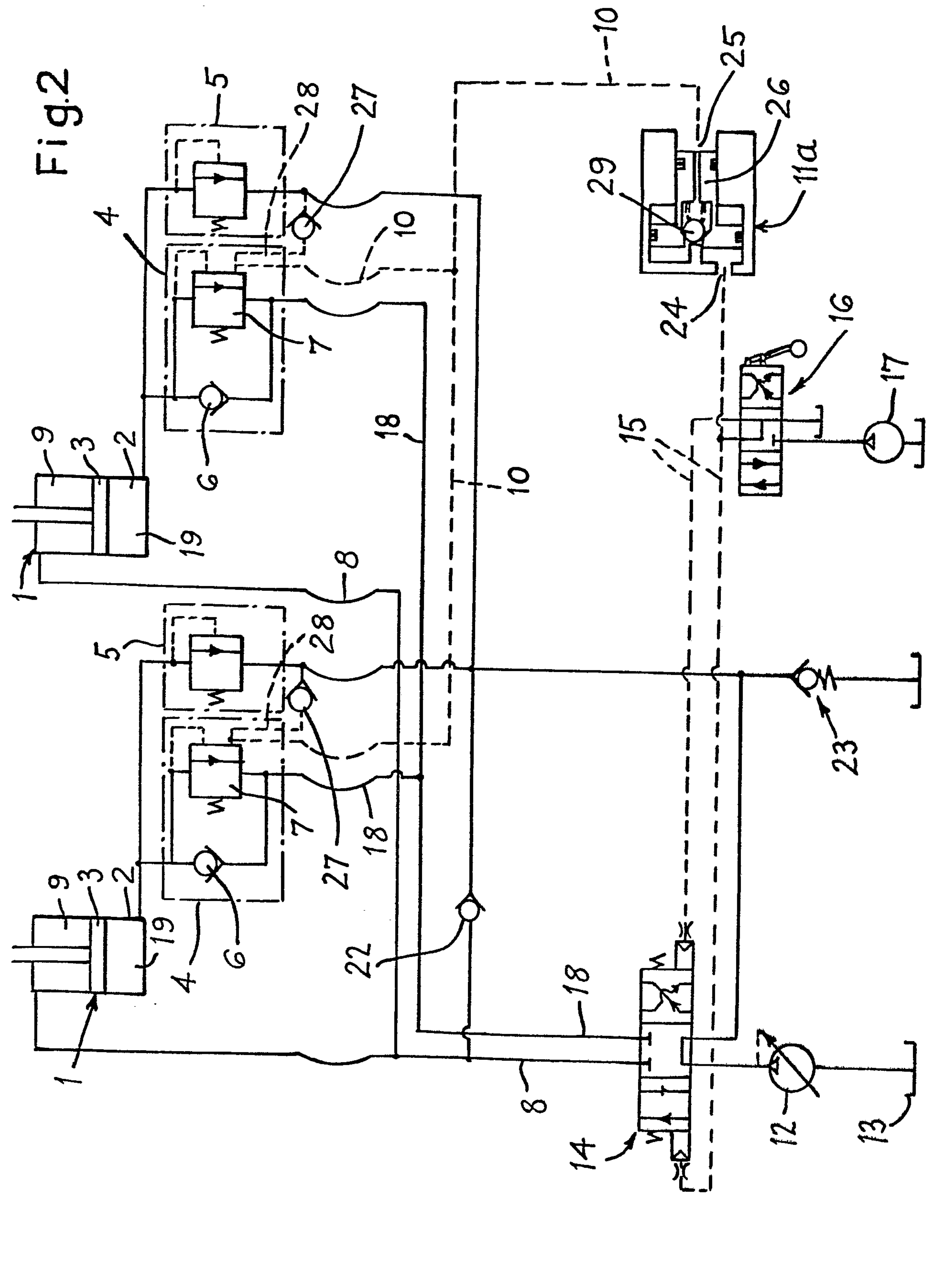

Fig.2

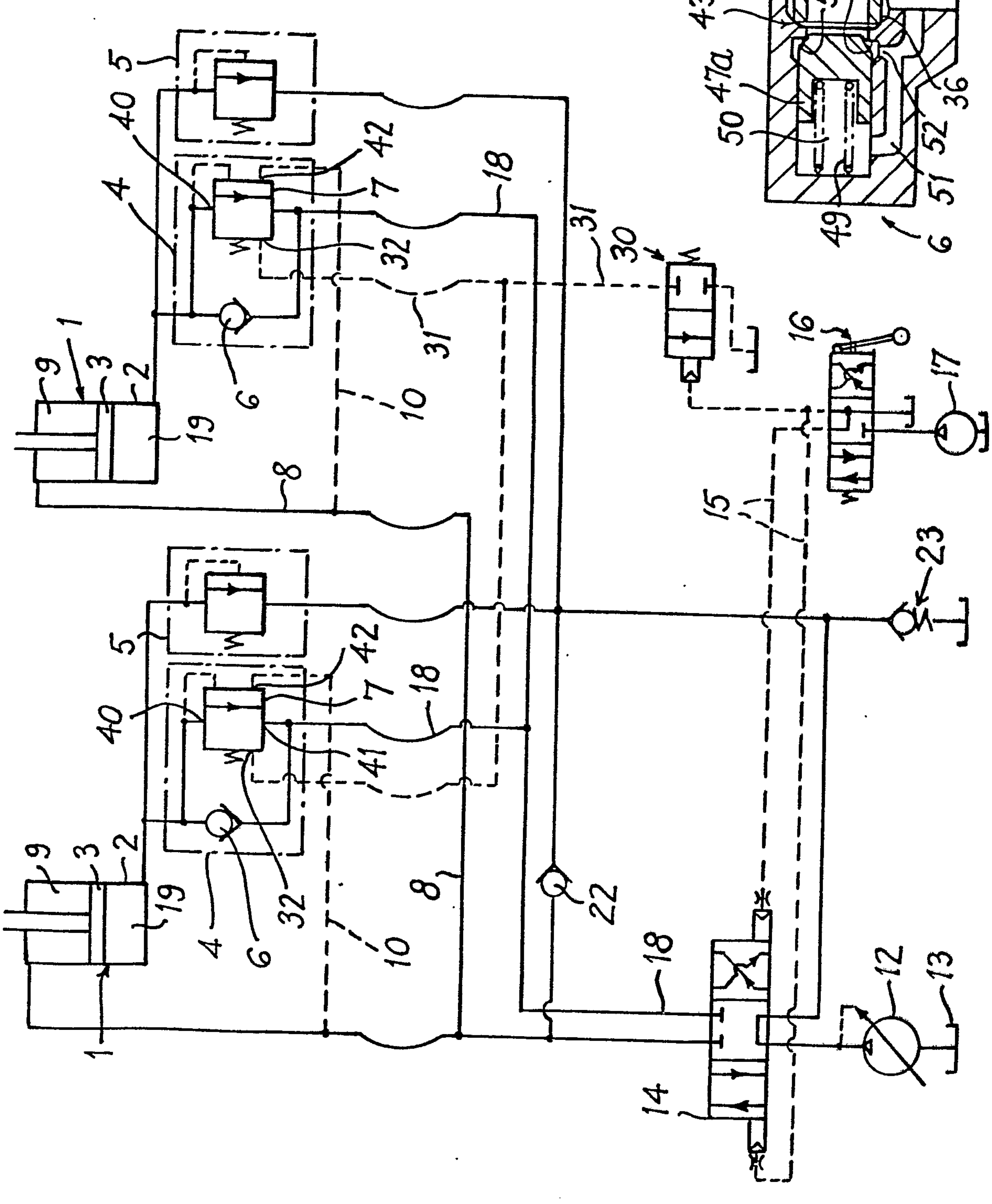
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Fig.3

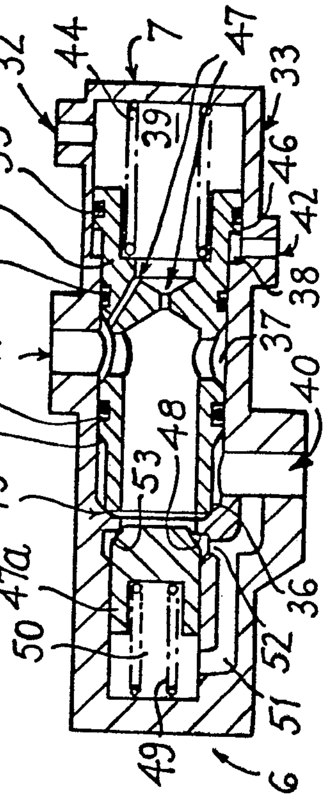
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Fig.4

European Patent Office

EUROPEAN SEARCH REPORT

0063025
Application number

EP 82 30 1825

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
A	DE-A-1 550 452 (PRESCH) * page 2, line 33 - page 4; figure *	1,2,3, 10	F 15 B 11/08
A	DE-A-2 424 973 (MONTAN-HYDRAULIK) * page 6, lines 8-19; page 10, line 16 - page 13, line 18; figure *	1	
A	DE-A-1 600 970 (VEB SPEZIALFAHRZEUGWERK BERLIN) * page 5, lines 7-8 *	6	
A	US-A-3 943 825 (BIANCHETTA et al.) * page 2, line 28 - page 6, line 14; page 6, line 60 - page 7, line 67; figure 1 *	7,8,9, 10	TECHNICAL FIELDS SEARCHED (Int. Cl. 3) F 15 B
A	GB-A- 929 481 (NEW YORK AIRBRAKE COMP.) * page 3, line 73 - page 4, line 8; figure *	7,9	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	28-07-1982	WENZEL A.R.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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