# United States Patent

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[54] **HYDRAULIC POWER CIRCUIT WITH RAPID LOWERING PROVISIONS**
5 Claims, 2 Drawing Figs.

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[51] Int. Cl. .......... F15b 11/08, F15b 13/04
[50] Field of Search .......... 91/420, 421, 437, 438, 444, 436; 60/52 HE

[56] References Cited
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|---|---|---|---|
| 3,033,168 | 5/1962 | Ruhl | 91/438 X |
| 3,049,101 | 8/1962 | Ruhl | 91/420 |
| 3,267,961 | 8/1966 | Rice | 91/436 X |
| 3,477,347 | 11/1969 | Rice | 91/438 |

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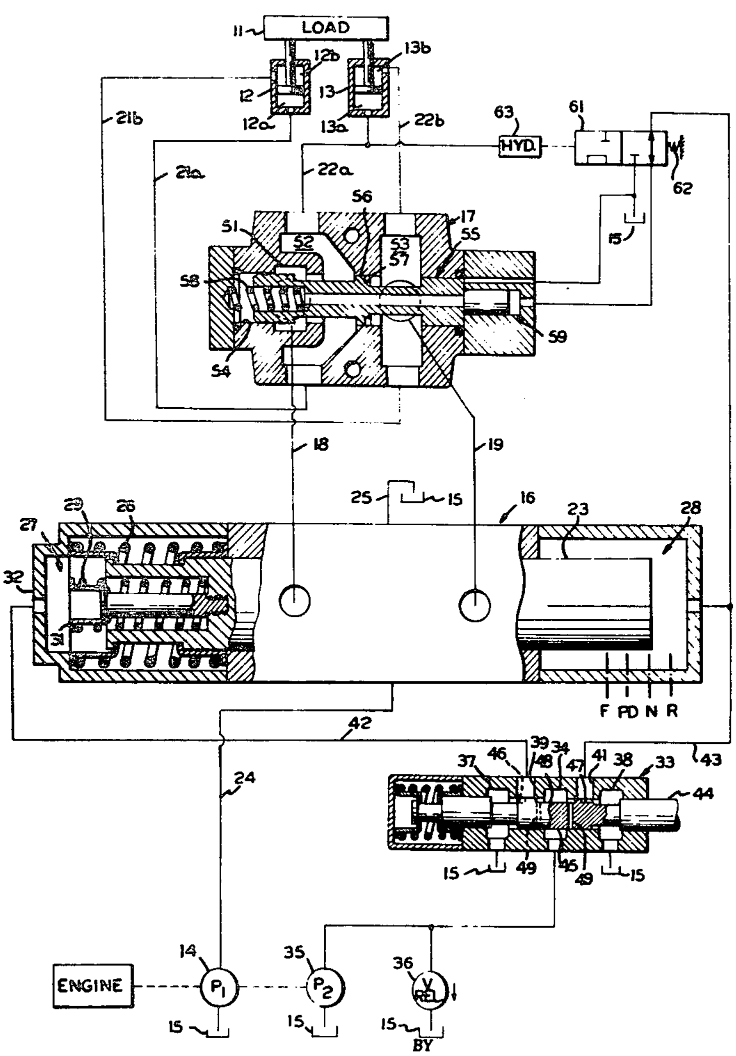
ABSTRACT: A hydraulic power circuit especially useful as a lift circuit for front-end loaders and including a bypass valve separate from the directional control valve which is adapted to interconnect the contracting and expanding ends of the actuating cylinders and permit rapid lowering of the implement. The circuit is characterized by an actuating scheme for the bypass valve which opens that valve only when the directional control valve is shifted to float position and the load pressure in the contracting ends of the cylinders is below a preselected value. The directional control valve may be shifted by pilot pressures, and in this case the motive force for opening the bypass valve may be developed by the pressure in the pilot circuit.



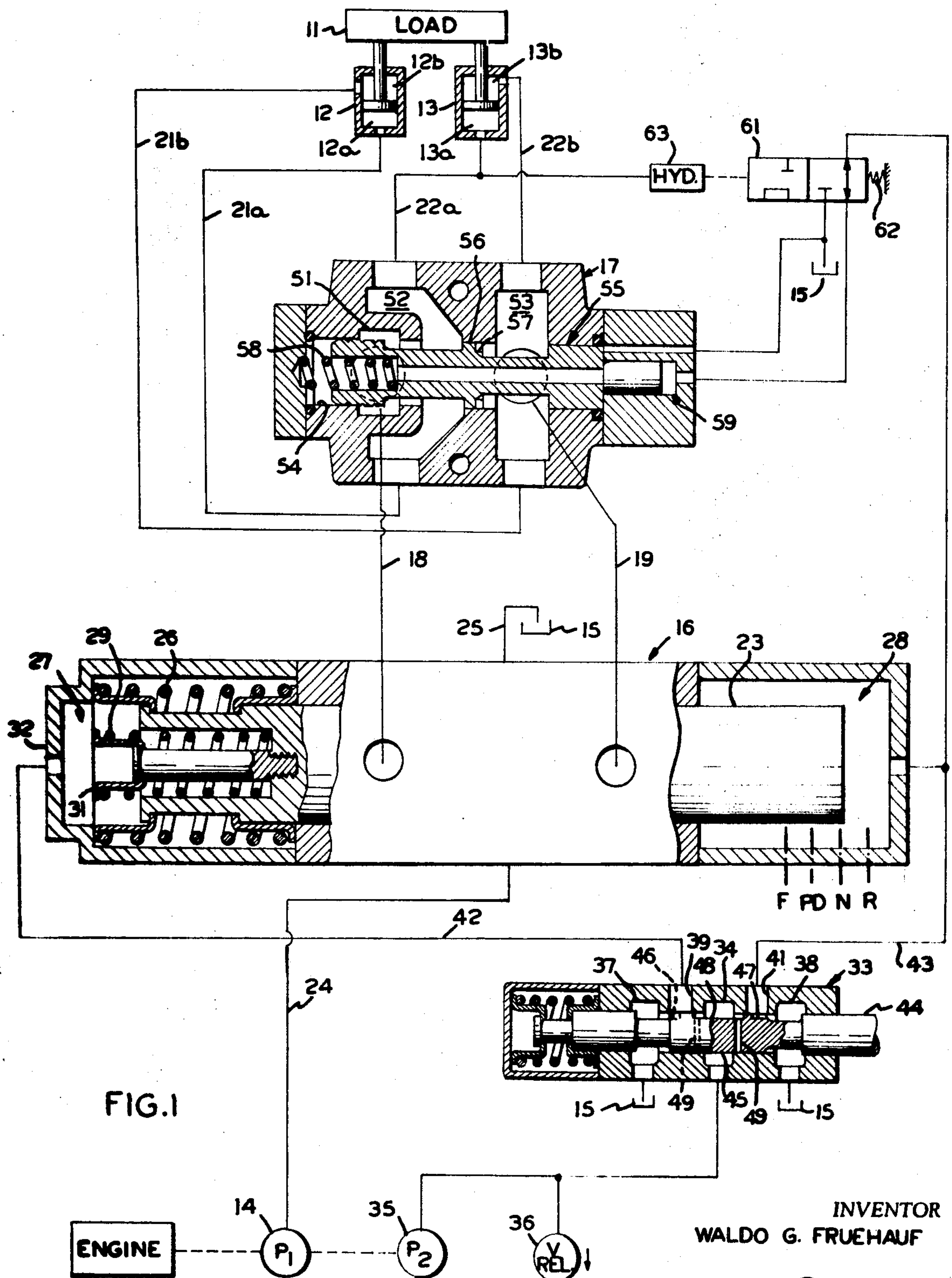



FIG. 1

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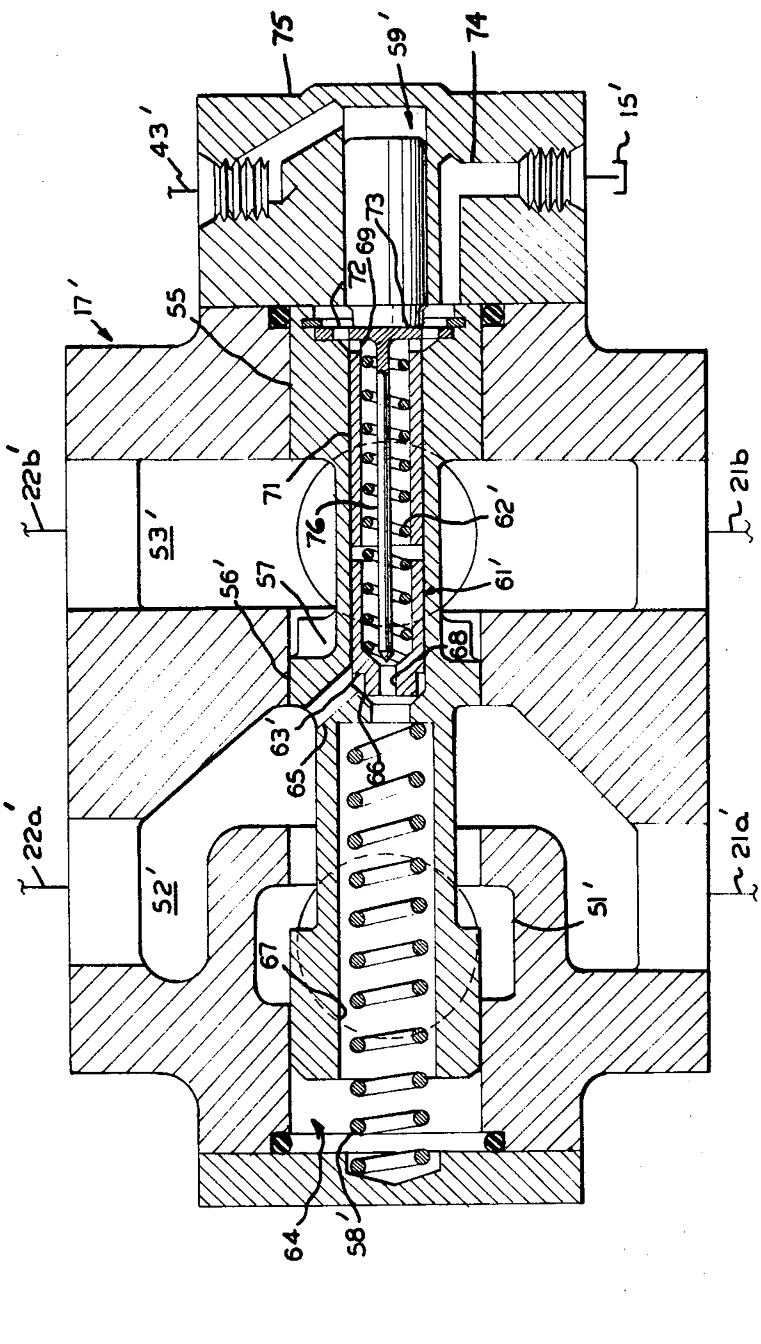


FIG. 2

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## HYDRAULIC POWER CIRCUIT WITH RAPID LOWERING PROVISIONS

### BACKGROUND OF THE INVENTION

Many hydraulic power circuits are used today to actuate components subject to large, unidirectional, external loads, usually gravitational loads. A good example is the lift circuit employed on front end loaders. In this circuit, the bucket-carrying boom commonly is positioned by a pair of parallel-connected double-acting piston motors, hereinafter called cylinders, of the differential area-type which are installed in such manner that the load imposed by the boom tends to contract their head ends. The cylinders are controlled by a directional control valve which affords the following positions: a "-neutral" or "hold" position in which the cylinders are hydraulically locked, a "raise" position in which the head and rod ends of the cylinders are connected with a supply pump and tank, respectively, a "power down" position in which the connections between the cylinders and the pump and tank are reversed, and a "float" position in which the rod and head ends of the cylinders are interconnected through a regeneration path which is provided with a restricted bleed connection through which the oil displaced by the cylinder rods can escape to the tank. The "power down" position is used for digging, whereas the "float" position is used to effect rapid dropping of an empty bucket from an elevated position.

During the bucket-dropping operation of the conventional circuit, all of the oil transferred from the contracting head ends to the expanding rod ends of the cylinders must return to and flow through the directional control valve, and then be redelivered to the cylinders. The restriction to flow through this regeneration path can be quite high because the lines interconnecting the cylinders and the valve frequently are long, and also because the valve itself normally is sized to handle the output of the supply pump and not the much greater flow rate required for rapid dropping of the bucket. Therefore, it should be evident that, in order to maintain the expanding ends of the cylinders liquid-filled, and thus preclude cavitation, it is necessary to establish a relatively high pressure at the directional control valve. This can be accomplished only be severely restricting the bleed connection through which the oil displaced by the cylinder rods escapes to tank, and this necessarily limits the maximum speed at which the boom can descent.

In an effort to improve the performance of the conventional circuit, it has been proposed to incorporate a separate bypass valve located at or near the cylinders and which serves to divert directly to the expanding ends of the cylinders some or all of the oil displaced from the contracting ends. Some versions of this proposal are disclosed in U.S. Pat. Nos. 3,033,168; 3,049,101; 3,267,961 and 3,477,347. While each of these schemes is effective to increase the drop speed of the implement, and some have the added advantage of ensuring that quick drop action occurs only when the directional control valve is in float position, all of the designs suffer from the fact that they are based in the assumption either that the load imposed on the cylinders is substantially constant, or, in the case of a loader bucket, that the operator will initiate quick drop action only when the bucket is empty. Therefore, if any of these schemes is used on a loader and the directional control valve is shifted to a position which will produce quick drop action while a full bucket is elevated, the boom will descend at an excessive speed so great that the operator will be powerless to stop or even retard it. This condition could easily cause damage to the equipment or severe injury to operating personnel.

The object of the present invention is to provide an improved power circuit including a quick drop bypass valve which not only minimizes inadvertent initiation of quick drop action, as in some of the prior circuits, but also prevents dropping of the load at excessive speeds. According to the invention, the actuation scheme for the bypass valve establishes two conditions which must be satisfied before that valve will open. The first condition is that the directional control valve must be shifted to float position. Since this position usually lies at the opposite side of the power down position from the neutral position, imposition of this condition minimizes the risk of inadvertent initiation of quick drop action. The second condition precedent to opening of the bypass valve is that the load pressure in the contracting ends of the cylinders must be below a predetermined level indicative of the maximum load which can safely be lowered while quick drop action is in effect. Inclusion of this added condition provides positive insurance against dangerous rates of descent under all conditions of operation.

In embodiments of the invention using pilot operated directional control valves and spool-type bypass valves, the actuation scheme for the bypass valve preferably is so designed that the pilot pressure signal which shifts the directional control valve to float position develops the motive force which opens the bypass valve. This can be done in several ways. One possibility is to provide the bypass valve with a pressure motor which opens it against a substantially constant bias, and to incorporate a shuttle valve which selectively vents this motor or pressurizes it with fluid drawn from the pilot circuit in accordance with the level of the load pressure in the actuating cylinders. Another possibility consists in connecting the valve-opening motor in continuous communication with the pilot system, and in equipping the bypass valve with an opposed fluid pressure motor which is selectively vented or pressurized by fluid taken from the contracting ends of the cylinders by a load pressure responsive shuttle valve.

In embodiments where in a poppet-type bypass valve is used or the directional control valve is actuated directly by the operator, the bypass valve may be controlled by a triggering scheme similar to that shown in Fig. 2 of U.S. Pat. No. 3,267,961, but including an additional vent valve in series with the vent valve in the directional control valve and which opens and closes the pilot vent path depending upon whether the load pressure in the cylinders is below or above, respectively, the critical level.

### BRIEF DESCRIPTION OF THE DRAWINGS

Several embodiments of the invention are described herein with reference to the accompanying drawings in which:

FIG. 1 is a schematic diagram showing one version of the new circuit incorporating a pilot-operated directional control valve.

FIG. 2 is a sectional view of a modified bypass valve which may be used in the Fig. 1 circuit.

### DESCRIPTION OF THE EMBODIMENT OF FIG. 1

Referring to Fig. 1, the improved circuit is employed to actuate a load **11**, which may represent the boom of a front-end loader, and includes a pair of differential area power cylinders **12** and **13**, a supply pump **14** and oil reservoir or tank **15**, a four-position directional control valve **16**, and a regenerative bypass valve **17**. The last mentioned valve is located at or near cylinders **12** and **13** and serves to connect them in parallel across the main service lines **18** and **19** leading from directional control valve **16**; the head ends **12*a*** and **13*a*** of the cylinders being joined to service line **18** via branch lines **21*a*** and **22*a***, and the rod ends **12*b*** and **13*b*** being joined to service line **19** via branch lines **21*b*** and **22*b***.

Although in actual practice pump **14** usually supplies several actuating circuits controlled by separate directional control valve units mounted in a common housing, for convenience and clarity the illustrated valve **16** includes only the valve unit pertaining to the circuit of the invention. This unit comprises a conventional hollow valve plunger **23** having the following four operative positions: a neutral or hold position N in which it unloads pump **14** to tank **15** through an open center unloading path and precludes flow to and from each of the service lines **18** and **19**; a raise position R in which it closes the open center path and connects service lines **18** and **19** with supply line 24 and tank line 25, respectively; a power down position PD in which it closes the open center path and reverses the connections between the service lines and lines 24 and 25; and a float position F in which it unloads pump 14 and interconnects service lines 18 and 19 through a regeneration path having a restricted bleed connection to tank line 25. Valve plunger 23 is biased to the neutral position by a centering spring 26 and is shifted in opposite directions from this position by a pair of opposed piloted motors 27 and 28, each of which includes one end of the plunger itself. A second spring 29, having a seat 31 which abuts left end cap 32 in the power down position, supplements the bias of spring 26 as plunger 23 moves to the left from power down position. This expedient reduces the risk that the operator will unintentionally move plunger 23 to float position.

Motors 27 and 28 are operated by pilot pressures supplied to them from a closed center, manually operated, pressure-graduating pilot valve 33. This valve includes an inlet chamber 35 which is connected to receive oil from a small pilot pump 35 at a low pressure (e.g. 200 p.s.i.) determined by relief valve 36, a pair of exhaust chambers 37 and 38 which are connected with tank 15, and a pair of motor ports 39 and 41 which are connected with the motors 27 and 28, respectively, through pilot passages 42 and 43. The pressures at ports 39 and 41 are varied by a sliding valve spool 44 which is provided with a land 45 having a throttling notch 46 or 47 at each end and an axially aligned centrally located, stopped flat 48. The spool is keyed against rotation so that the flat and the notches may register with motor ports 39 and 41, and is provided with through transverse passages 49 which balance the radially directed pressure forces. When spool 44 is in the illustrated neutral position, land 45 isolates inlet chamber 34 from the motor ports and the other chambers, and notches 46 and 47 connect the motor ports with exhaust chambers 37 and 38, respectively. Therefore, under this condition, both of the ports 39 and 41 are vented. As the spool is shifted to the left, port 41 remains vented, but the flow path from port 39 to chamber 37 through notch 46 is gradually restricted, and the peripheral spool edge at the left end of flat 48 gradually opens a flow path from chamber 34 to port 39. Therefore, this movement of spool 44 causes the pressure at port 39 to increase progressively relatively to the pressure at port 41. In a similar manner, rightward movement of the spool effects a progressive increase in the pressure at port 41 relative to the pressure at port 39.

Bypass valve 17 comprises a housing formed with three cored chambers 51–53 which are provided with ports through which they are connected with the hydraulic lines 18, 19, 21*a*, 21*b*, 22*a* and 22*b* in the manner shown in the drawing, and which are spanned by a valve bore 54. This bore contains a reciprocable valve plunger 55 provided with a central land 56 containing a plurality of circumferentially spaced metering slots 57. Valve plunger 55 is biased by compression spring 58 to the illustrated closed position, in which land 56 prevents communication between chambers 52 and 53, and is shifted to the left to open a regeneration path between these chambers by a piston motor 59. This motor is selectively connected with pilot conduit 43 or tank 15 via a shuttle valve 61 which is biased to the illustrated pressurizing position by a spring 62 and is moved to the venting position by an actuating motor 63 which responds to the load pressure in the head ends of cylinders 12 and 13. The size of motor 59 is so correlated with the preload in spring 58 that the motor is able to shift plunger 55 to open position only when it is pressurized to the level which enables piloted motor 28 to move plunger 23 to float position. Motor 63 and spring 62, on the other hand, are so sized that shuttle valve 61 transmits pilot pressure to motor 59 only as long as the pressure in cylinder ends 12*a* and 13*a* is below a predetermined value indicative of the maximum load which can be lowered safely using quick drop action.

When the improved circuit is in service and the spool 44 of pilot valve 33 in in neutral position, pilot conduits 42 and 43 will be vented to tank 15. Therefore, centering spring 26 will hold plunger 23 of directional control valve 16 in neutral position, and, regardless of the position of shuttle valve 61, spring 58 will keep bypass valve 17 closed.

Raising of load 11 is effected by shifting spool 44 to the left from neutral position to thereby increase the pressure in pilot conduit 42 and cause piloted motor 27 to shift valve plunger 23 to its raise position R. Oil delivered by pump 14 is now supplied to the head ends of cylinders 12 and 13 via lines 24 and 18, chambers 51 and 52 and branch lines 21*a* and 22*a*, and the oil displaced from the rod ends 12*b* and 13*b* of the cylinders is returned to tank is via branch lines 21*b* and 22*b*, chamber 53, and lines 19 and 25. Since pilot conduit 43 remains vented during the raising operation, bypass valve 17 will stay closed regardless of the position of shuttle valve 61.

In order to force load 11 down against an opposing external force, the operator will shift spool 44 to the right from neutral position. This action raises the pressure in pilot conduit 43 and causes motor 28 to shift valve plunger 23 to the left to its power down PD position. Now oil is supplied to the rod ends of the cylinders 12 and 13 through lines 24 and 19, chamber 53 and branch lines 21*b* and 22*b*, and the oil displaced from the head ends 12*a* and 22*a*, passages 52 and 51, and lines 18 and 25. During this operation the pressure in head ends 12*a* and 13*a* will be well below the setting of valve 61, so spring 62 will move the latter to the illustrated pressurizing position. However, since the pilot pressure which causes motor 28 to move plunger 23 to power down position is not high enough to enable motor 59 to overcome the preload in spring 58, bypass valve 17 will remain closed.

When load 11 is in an elevated position from which it is to descent under the action of its own weight, the operator shifts spool 44 to the right beyond the position employed during power down operation. This movement causes valve 33 to develop in conduit 43 the substantially higher pilot pressure which motor 28 needs in order to overcome the combined forces of springs 26 and 29, and thereby causes that motor to shift plunger 16 to float position F. If the load 11 is too large for safe quick drop action, the pressure in head ends 12*a* and 13*a* will be above the setting of valve 61; therefore, motor 63 will hold this valve in its venting position and preclude opening of bypass valve 17. Under this condition, all of the oil displaced from head ends 12*a* and 13*a* will be returned to directional control valve 16, where the volume attributable to rod displacement will be directed to tank 15 and the balance will pass through the regeneration path in plunger 23 and be redelivered to the rod ends 12*b* and 13*b* via service line 19, chamber 53 and branch lines 21*b* and 22*b*. On the other hand, if load 11 is not excessive, the pressure in head ends 12*a* and 13*a* will be below the setting of valve 61, and spring 62 will place this valve in pressurizing position. Since during this mode of operation the pilot pressure in conduit 43 is high enough to enable motor 59 to overcome the bias of spring 58, that motor will open valve 17 and establish direct communication between chambers 52 and 53. As a result, oil expelled from head ends 12*a* and 13*a* will be transferred to rod ends 12*b* and 13*b* through two parallel paths; one being the direct path between chambers 52 and 53 established by valve 17, and the other being the regeneration path provided by the plunger 23 of directional control valve 16. Since opening of the supplemental regeneration path reduces the total restriction to flow from the contracting to the expanding ends of the cylinders, the light load 11 will descend rapidly. In the case of a lift circuit for a front-end loader, it is preferred that the flow paths through valve 17 be so sized that the boom will descend at substantially the same speed regardless of whether the bucket is loaded, and consequently valve 17 is closed, or the bucket is empty and valve 17 is open.

## DESCRIPTION OF THE FIG. 2 EMBODIMENT

Figure 2 shows a modified bypass valve 17′ incorporating an alternative actuation scheme which accomplishes the same end result as the one employed in Fig. 1, but should be less expensive to manufacture. In this embodiment, the motor 59′, which shifts bypass plunger 55′ in the opening direction, is in continuous communication with pilot conduit 43' and is opposed by a pressure motor 64 as well as by spring 58'. The added motor 64 is selectively pressurized with fluid from chamber 52' or vented to tank 15' by a shuttle valve 61' located within valve plunger 55'.

Valve 61' is biased to the illustrated venting position by compression spring 62' and is shifted to the pressurizing position by the fluid in chamber 52' which is applied to its motor surface 63' through a passage 65 formed in plunger 55'. In the venting position, valve 61' engages its seat 66, to thereby block communication between motor 64 and chamber 52' through passages 67 and 65, and allows the oil in motor 64 to escape substantially freely to tank 15 via an exhaust path including passage 67, an axial passage 68 in valve 61', the slots 69 in the right end of stop sleeve 71, the through passages 72 in spider member 73, and a passage 74 in casing 75. Spring 62' is sized to keep valve 61' in the venting position when the load pressure in chamber 52' is below the critical level indicative of an excessive load; therefore, as in the Fig. 1 embodiment, motor 59' will be able to open bypass valve 17' when the pilot pressure it receives reaches the level which will cause the directional control valve to shift to float position.

When the load pressure in chamber 52' rises above the setting of valve 61', the valve will shift to the right to the pressurizing position in which it abuts sleeve 71. This action opens communication between chamber 52' and motor 64 and simultaneously causes a pin 76 carried by spider 73 to move into and thus restrict axial passage 68 in the exhaust path leading from motor 64. The restriction to flow through passage 68 is considerably greater than the restriction to flow from chamber 52' to motor 64 through passages 65 and 67; therefore, motor 64 will be subjected to a substantial back pressure proportional to the load pressure in chamber 52'. As a result, motor 64 will supplement the biasing force exerted by spring 58' and hold valve plunger 55' in its closed position even when motor 59' is subjected to maximum pressure which can be produced by the pilot circuit. Thus, as in the Fig. 1 embodiment, quick drop action is precluded when the load is too large for this action to be afforded safely.

Since the illustrated embodiments use spool-type bypass valves and pilot-operated directional control valves, it is convenient to use fluid in the pilot circuit as the motive fluid for opening the bypass valve. However, it should be evident that this type of actuation scheme could not be used in circuits employing manually operated directional control valves, and that it probably would be impractical in circuits where poppet-type bypass valves were used. In both of these cases, the bypass valve may be actuated by a scheme similar to the one shown in Fig. 2 of U.S. Pat. No. 3,267,961, but including a load-pressure-responsive vent valve which is in series with the one controlled by the directional control valve and which is opened and closed, respectively, when the load pressure is below and above the critical level.

I claim:

1. In a hydraulic system including a double-acting cylinder (12 or 13) having opposed ends 12*a*, 12*b* or 13*a*, 13*b*) and arranged to actuate a load (11) which tends to contract the first (12*a* or 13*a*) of said ends, directional control valve means (16, 33) for controlling flow to and from said ends and having a float condition in which it establishes a regeneration path between the cylinder ends, and a separate bypass valve (17 or 17') arranged to open and close a second regeneration path between the cylinder ends, the improvement which comprises actuating means (58, 59, 61–63 or 58', 59', 61'–63', 64) for opening the bypass valve (17 or 17') only when the pressure in the first cylinder end (12*a* or 13*a*) is below a predetermined level and the directional control valve means (16, 33) is in float condition.

2. The improved hydraulic system defined in claim 1 in which the actuating means includes

a. means (58) biasing the bypass valve (17) in the closing direction;

b. a pressure motor (59) for shifting the bypass valve in the opening direction; and

c. means (61–63) effective when the pressure in said first cylinder end (12*a* or 13*a*) is below said predetermined level and the directional control valve means is in float condition to subject said pressure motor (59) to a pressure sufficient to enable it to overcome the biasing means, and effective at all other times to subject said pressure motor to a lower pressure.



3. The improved hydraulic system defined in claim 1 in which

a. the directional control valve means includes a directional control valve m (16) having a float position in which it establishes said regeneration path, piloting means (14, 15, 33) for producing a variable pilot pressure, and a first fluid pressure motor (28) which responds to the pilot pressure and shifts the directional control valve to float position when the pilot pressure has a predetermined magnitude; and

b. the actuating means includes

1. A second fluid pressure motor (59) arranged to open the bypass valve (17) against the opposition of a biasing means (58) when subjected to a pressure of said predetermined magnitude, and
2. shuttle valve means (61–63) responsive to the pressure in the first cylinder end (12*a* or 13*a*) for subjecting the second fluid pressure motor to said pilot pressure when the cylinder pressure is below said predetermined level, and, when cylinder pressure is above said level, for venting the second motor.

4. The improved hydraulic system defined in claim 1 in which the actuating means includes

a. a first pressure motor (59') for moving the bypass valve (17') in the opening direction;

b. means (14, 33) for supplying fluid under pressure to the first motor;

c. a second pressure motor (64) for moving the bypass valve in the closing direction; and

d. means, including a valve (61') which responds to the pressure in said first cylinder end (12*a* or 13*a*), for subjecting the second motor (64) to a pressure sufficient to enable it to hold the bypass valve closed when the pressure in said cylinder end is above said predetermined level.

5. The improved hydraulic system defined in claim 1 in which

a. the directional control valve means includes a directional control valve (16) having a float position in which it establishes said regeneration path, piloting means (14, 15, 33) for producing a variable pilot pressure, and a first fluid pressure motor (28) which responds to the pilot pressure and shifts the directional control valve to float position when the pilot pressure has a predetermined magnitude; and

b. the actuating means includes

1. a second pressure motor (59') subject continuously to said pilot pressure and sized to open the bypass valve (17') at a pilot pressure of said predetermined magnitude,
2. a third fluid pressure motor (64) effective when pressurized to a certain level to maintain the bypass valve closed, and
3. valve means (61'–63') responsive to the pressure in said first cylinder end (12*a* or 13*a*) for venting the third fluid pressure motor or pressurizing same to said certain level with fluid from said first cylinder end depending upon whether the pressure in the first cylinder end is below or above, respectively, said predetermined level.