# United States Patent

**Knapp**

[15] **3,654,837**

[45] **Apr. 11, 1972**


## [54] HYDRAULIC CONTROL SYSTEMS


[72] Inventor: **Kenneth K. Knapp,** Columbus, Ohio

[73] Assignee: **Abex Corporation,** New York, N.Y.



[22] Filed: **Dec. 29, 1969**

[21] Appl. No.: **888,533**

[52] **U.S. Cl.** ..... **91/461,** 91/468, 137/503

[51] **Int. Cl.** ..... **F15b 13/042**

[58] **Field of Search** ..... 91/446, 461, 468, 420; 137/503



[56] **References Cited**

UNITED STATES PATENTS

| | | | |
|---|---|---|---|
| 1,581,454 | 4/1926 | Larson | 137/503 X |
| 2,374,568 | 4/1945 | Terry | 137/503 |
| 3,378,028 | 4/1968 | Mosher | 137/503 |
| 2,146,537 | 2/1939 | Farnham | 91/468 X |
| 2,376,519 | 5/1945 | Staly | 91/461 X |
| 2,900,960 | 8/1959 | Gratzmuller | 91/461 X |
| 2,982,258 | 5/1961 | Farkas | 91/468 X |
| 3,234,857 | 2/1966 | De Castelet | 91/461 X |



*Primary Examiner*—Edgar W. Geoghegan
*Assistant Examiner*—Irwin C. Cohen
*Attorney*—Kinzer, Dorn and Zickert

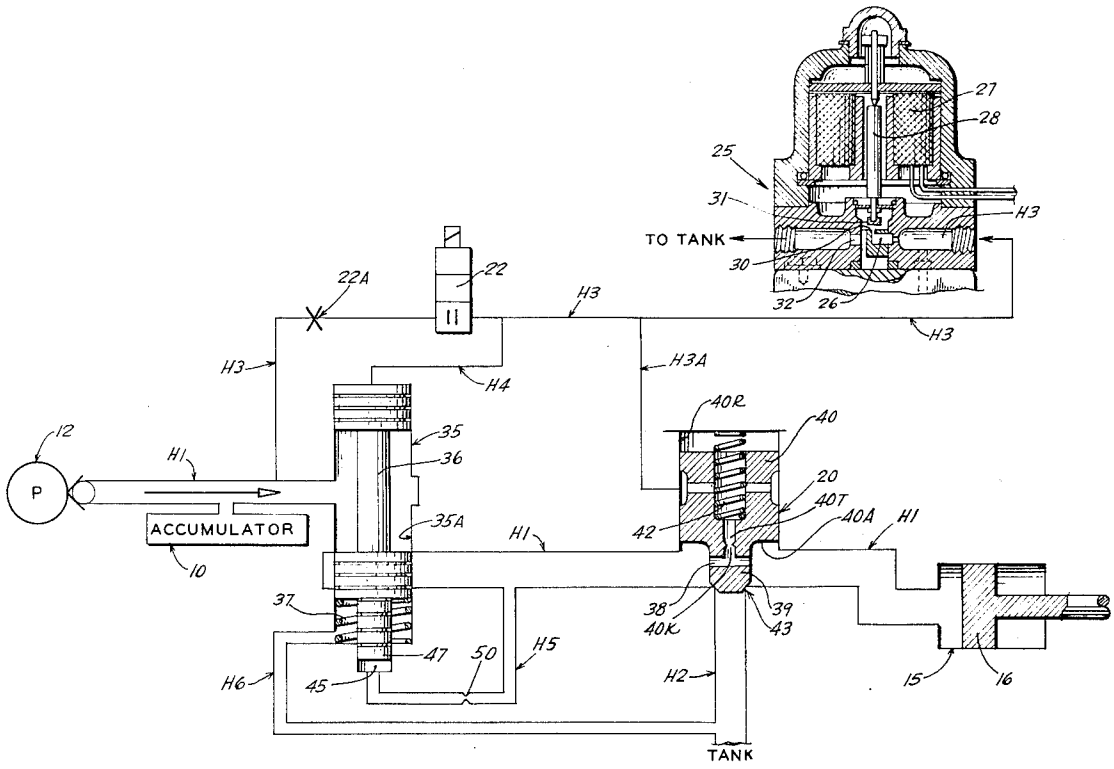


[57] **ABSTRACT**

A hydraulic system comprises a source of fluid under pressure, supplying working fluid through a supply line, and a flow control valve of the spool type is interposed in the supply line between the source and the work performing means. The flow control valve is itself controlled by pressure in two pilot lines. One pilot line tends to open the valve, and pressure therein is controlled by a variable pressure control valve. The second pilot line is connected to the supply line downstream of the flow control valve so that pressure in the second pilot line is an analog of the working pressure. The analog pressure in the second pilot line shifts the spool to its closed position at a value determined by the pressure in the first pilot line.

In the specific embodiment, the effect of the second pilot line closing the valve is to prevent an accumulator, the source of pressure, from being dumped or vented to the tank at a time when a relief valve in the supply line is opened.


**3 Claims, 3 Drawing Figures**



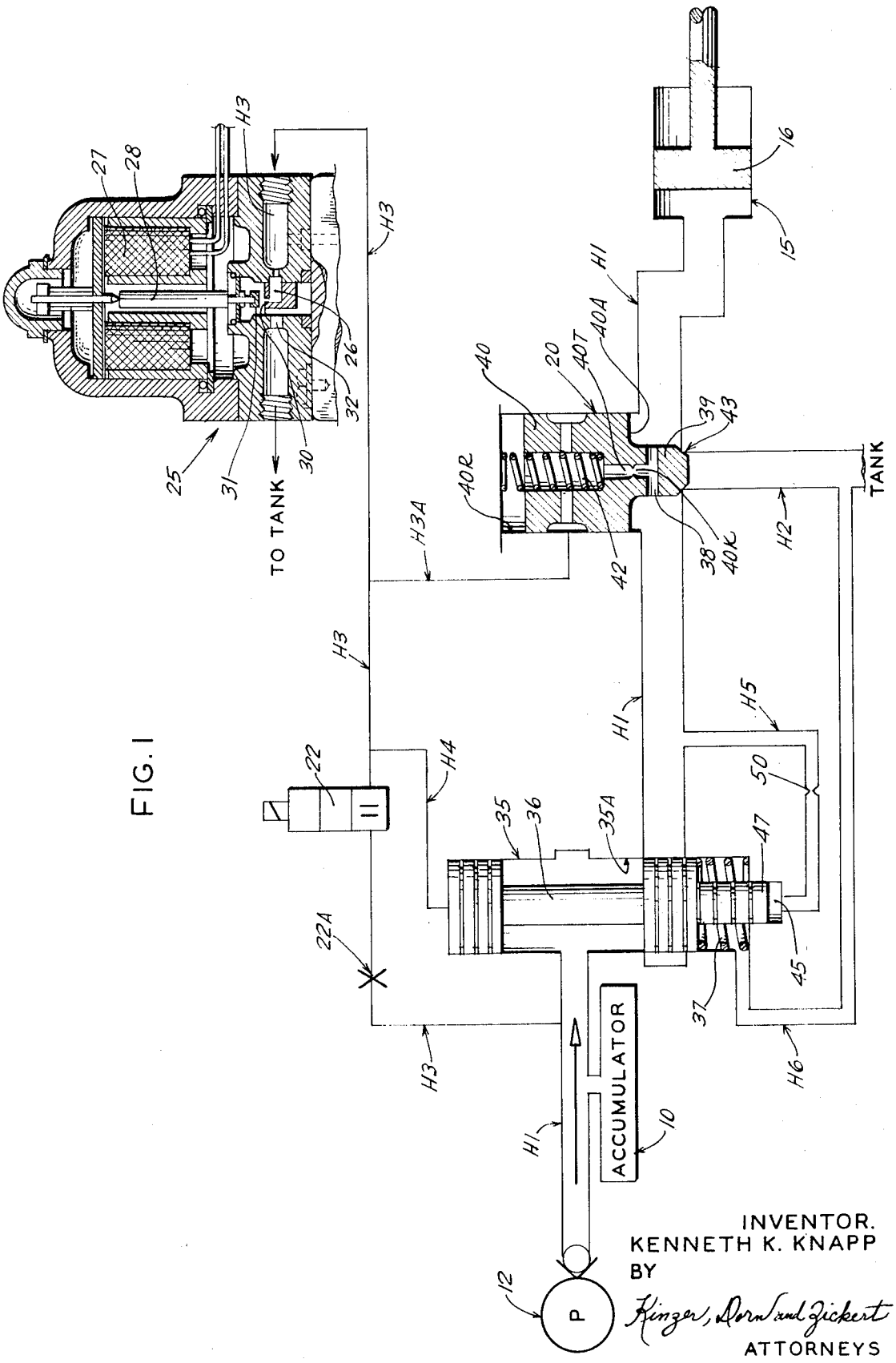



FIG. 1

INVENTOR.
KENNETH K. KNAPP
BY
Kinzer, Dorn and Zickert
ATTORNEYS

FIG. 2

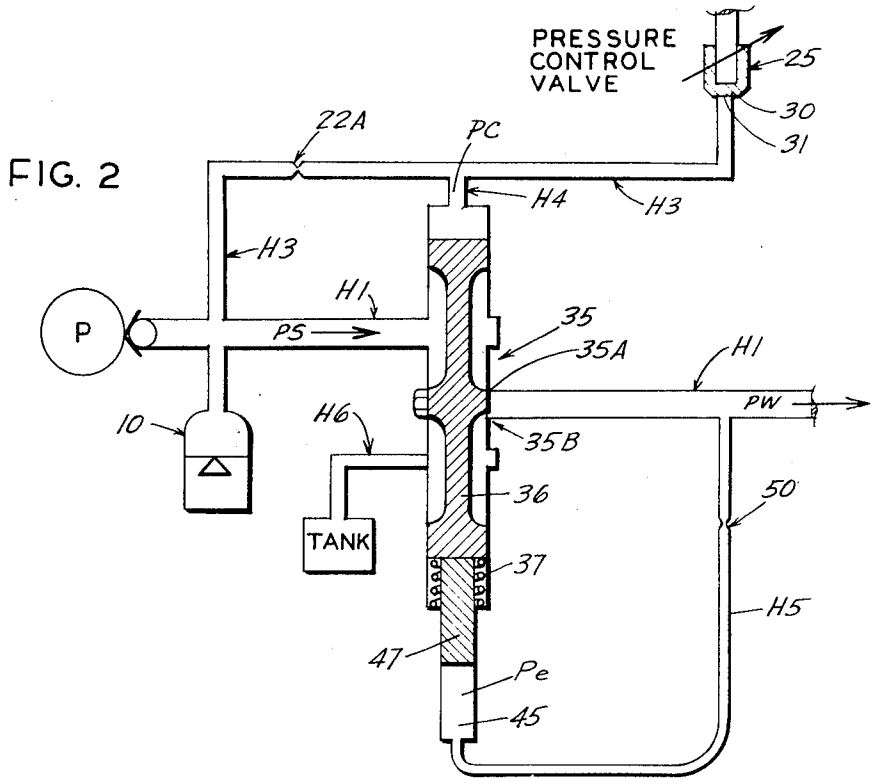
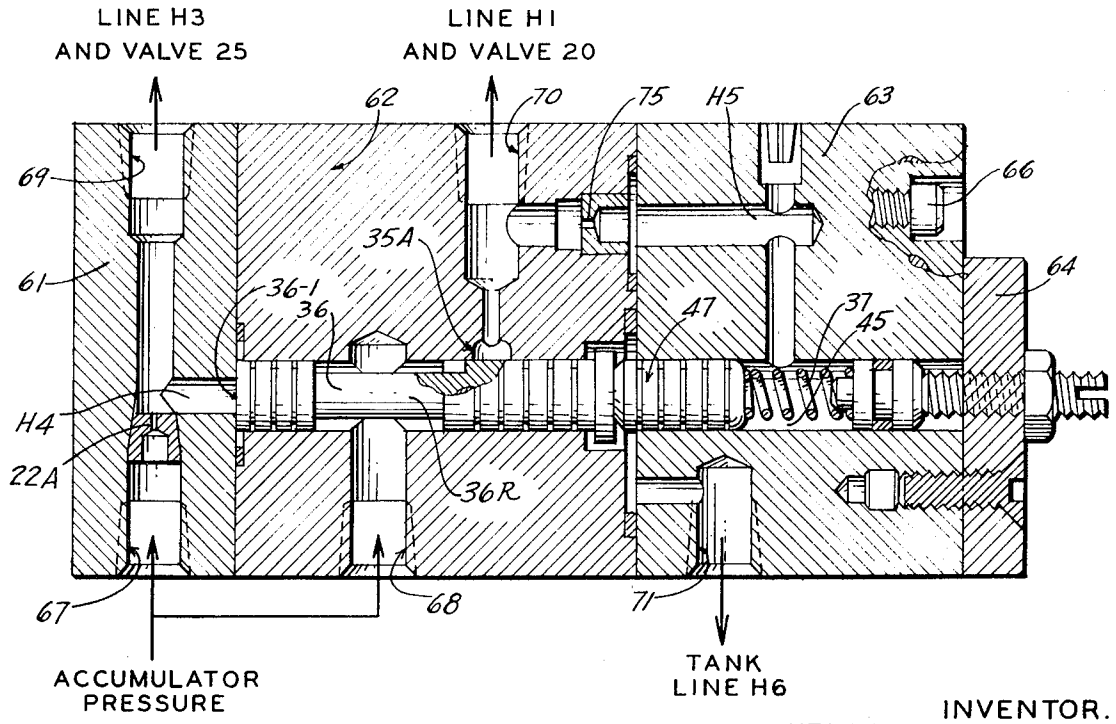



FIG. 3




INVENTOR.
KENNETH K. KNAPP
BY
Kinzer, Dorn and Zickert
ATTORNEYS

# HYDRAULIC CONTROL SYSTEMS

The present invention relates to a hydraulic system constructed specifically to conserve a pressure head against unnecessary loss or dissipation. The pressure head may be that represented by an accumulator which is to charge a supply line in the event of a power failure rendering ineffective the pump which normally pressurizes the system. This is only an example, and in fact it is possible to use the present invention on any system where pressure in a supply line is maintained by an accumulator. The accumulator may itself be charged by a pump, and the supply line may have a relief valve. The pump may be supplanted equivalently by an intensifier such as an air/oil intensifier which stalls out at a rated pressure value.

One such pump may supply many accumulators, each accumulator having imposed thereon the principle of the present invention. The hydraulic circuit of the present invention is particularly applicable to vehicle braking systems, such as those required for rapid transit rail vehicles, in which event the train may have a single pump for charging a main supply line connected to several accumulators on each car of the train.

Thus the present invention assumes that hydraulic requirements are to be obtained from an accumulator already in a charged state. The accumulator may or may not be an emergency source of pressure. The primary object of the present invention is to conserve the fluid supply in the accumulator, even though the accumulator is being discharged as an incident to furnishing pressure needs, as for example furnishing pressure needs for a vehicle brake system. Stated another way an object of the invention is to minimize accumulator overflow, as for example accumulator blow-down or excessive discharge through a relief valve at reduced brake pressure.

Specifically it is the object of the present invention to interpose in a hydraulic circuit a flow limiting valve for modulating the pressure in the supply line in such a fashion that as the applied working pressure reaches a predetermined high value, the passage through the flow limiting valve is restricted or altogether closed so that fluid under pressure in the accumulator is not wasted. This may be contrasted with the normal situation where fluid flow in excess of the working requirement might normally be discharged to the tank or reservoir through a relief valve without accomplishing useful work.

In actual operation the present system could be somewhat cyclical in nature, in that working pressure from the accumulator would be applied and then minimized. Consequently, the present invention may be employed as a system in a press where pressure is to be applied, reduced, re-applied and so on until the press has completed the assigned operation.

Another specific object of the present invention is to devise a hydraulic system in which a flow limiter valve in a supply line is monitored by a pressure control valve of the variantly positionable type, the control valve being responsive to (or itself monitored by) an analog of the conditions prevailing at the work performing means; further, the flow limiter valve is to be moved to a closed position to prevent the supply line from being charged by an accumulator in the event that pressure in the supply line approaches a state where a relief valve therein would normally open, this being accomplished by sensing the pressure in the supply line at a point between the flow limiter and the relief valve and positioning the flow limiter accordingly.

Other and further objects of the present invention will be apparent from the following description and claims and are illustrated in the accompanying drawings which, by way of illustration, show preferred embodiments of the present invention and the principles thereof and what is now considered to be the best mode contemplated for applying these principles. Other embodiments of the invention embodying the same or equivalent principles may be made as desired by those skilled in the art without departing from the present invention.

In the drawings:

FIG. 1 is a schematic view of hydraulic apparatus embodying the present invention;



FIG. 2 is a schematic view illustrating another embodiment of the present invention; and

FIG. 3 is a sectional view showing a preferred embodiment of the flow limiter valve of the present invention.

Referring to FIG. 1 an accumulator **10** is charged by a pump (or intensifier) **12**. The pump **12** will normally be furnishing the hydraulic requirements demanded by a cylinder **15** having a piston **16** therein adapted to operate a vehicle brake. It will be appreciated from the foregoing discussion, however, that the present invention in its aspect of utility is not limited to a vehicle brake system.

The description to follow assumes that the pump has become inoperative and that the accumulator is to serve in an emergency capacity. In this connection it may first be observed that the supply line H1, charged by the pump **12**, includes a relief valve **20** which opens the supply line to the tank, through line H2 as hereinafter described.

In the normal situation when there is no demand that fluid under pressure be delivered to the head end of cylinder **15**, a solenoid valve **22** is in a closed position and a pressure control valve **25** is in an open position. The solenoid valve serves as a flow control valve of secondary order. The solenoid valve is included in the system to further conserve the accumulator or other source of fluid under pressure. Thus a conduit H3, constituting a control line, communicates with the pump or accumulator side of the supply line H1 and is connected to one side of the solenoid valve **22**. Line H3 leads from the other side of the solenoid valve **22** to a passage **26** in the pressure control valve **25**. A restriction **22A** (see FIGS. **2** and **3**) is provided in line H3 in advance of solenoid **22**, but the restriction **22A** may be located as well on the downstream side of valve **22**. However, restriction **22A** should be on the upstream side of line H4 the function of which is set forth in more detail below.

Valve **25** has an electromagnet coil **27** as shown and an armature-mounted plunger **28** responsive to the magnetizing effect of the coil when energized. The plunger **28** is provided at its lower end with a poppet or valve element **30** adapted to modulate or meter variably the opening and closing of a valve seat **31** which communicates passage **26** with a passage **32** in valve **25** leading to the tank. It may be further mentioned that the intensity of the control circuit imposed on the electromagnet coil **27** is remotely determined as a measure of how effective valve **25** is to be. The remote control, for example, could be an analog of brake requirements, press requirements, or any other analog which is a profile of a demand for full pressure, a demand for nil pressure, or any intermediate value.

Thus, valve **25** is of the variable orifice type which is to say that the amount of flow past seat **31** per unit of time depends upon how far the poppet is displaced from the seat at a given pressure drop. In other words, the pressure in line H3 depends upon how far the poppet or valve element **30** is displaced from the seat **31** for a given flow through the valve. When the valve element **30** is fully displaced from the seat **31** as shown in FIG. **1**, line H3 is discharged to the tank or reservoir, and minimum pressure prevails therein characterizing quiescent flow at best.

Line H4 represents a pilot control conduit and is connected between line H3 and one end of a spool valve **35** downstream of the orifice. Valve **35** is the flow limiter valve characterizing the present invention.

When a signal is generated demanding, for example, application of the brakes, valve **22** is set to the "valve open" position communicating lines H3 and H4. The same brake signal energizes the coil **27** of valve **25**, actuating plunger **28** so that the valve element **30** closes on seat **31**. Pressure is thus built up in lines H3 and H4 and acts on the corresponding upper piston head of the spool **36** of valve **35** shifting the spool downward as viewed in FIG. **1** against the return spring **37**, disclosing passage **35A** of valve **35**. Consequently line H1 is continuous from the accumulator to the relief valve, which is to say that the accumulator is placed in communication with the relief valve side of line H1 which leads to the head end of cylinder **16**, noting that the fluid flowing in line H1 flows past and around the poppet **39** of relief valve **20**. The poppet has a

small diameter passage 38 therethrough for a purpose to be described. The fluid under pressure thus flowing to the head of the cylinder is effective to apply the brakes. (The lines for bleeding the rod end of the cylinder and returning the piston 16 are standard and are not shown.)

The poppet 39 includes a piston-type plunger 40 formed with a peripheral chamber or recess 40R intermediate its ends. The plunger also has an internal T-shaped cross passage 40T the ends of which communicate with chamber 40R and passage 38 by way of a restriction 40K therein as shown in FIG. 1. A spring 42 in the housing of valve 20 normally helps to hold the poppet 39 in closed position on a valve seat 43 in communicative relation with lines H1 and H2.

A pilot control line H3A communicates at one end with line H3 and at the other end with the chamber 40R in the poppet plunger. Thus, in the circumstance under consideration (accumulator pressure delivered to cylinder 15) line H3A is charged at the pressure of the accumulator and the fluid pressure in passages 38 and 40T soon equalizes. In other words, the entire area of plunger 40 above the restriction 40K (40R plus 40T plus the seat for spring 42) is at the pressure of line H3A. The effective area 40A of the plunger 40 below the restriction 40K is less. Valve 20 therefore stays in the steady position shown.

However, if the pressure demand signal to valve 25 should now become "pressure nil," valve 22 opens and the valve element 30 of valve 25 would fully disclose the seat 31; pressure in the pilot line H3A and chamber 40R will become nil. The underside of plunger 40 presents only the effective area 40A exposed to the fluid in line H1 which is still under accumulator pressure, but because of the greatly reduced (or even nil) pressure prevailing in chamber 40R at this time the relief valve 20 would open, discharging the accumulator through now open valve seat 43. This possibility of wasting the accumulator is obviated as will now be described.

A by-pass line H5 communicates with line H1 at one end, and at its opposite end opens into a chamber 45 in valve 35 at the underside of a piston or plunger 47 which may be viewed as an extension of the enlarged end of the spool 36 which is opposite the enlargement exposed to pilot pressure in line H4.

Line H5 is provided with a restriction 50 for damping and stability purposes. However, as pressure builds up in line H1, there is a proportional increase in line H5, and the proportioning of the areas of piston 47, spool 36, and poppet 39 as well as the spring forces and rates of springs 37 and 42 is such that when the pressure in line H5 is an analog of the pressure in line H1 which opens the relief valve 20, venting line H1, the pressure on piston 47 in chamber 45 is sufficient to concurrently shift spool 36 (upward) to close passage 35A. Thus, the proportioning is such that when the pressure in line H1 would be sufficient to open the relief valve, in effect venting the accumulator to line H2, valve spool 36 closes passage 35A, and venting of the accumulator is prevented. This conserves the supply of fluid under pressure in the accumulator. When opening 35A is thus fully closed, the relief valve is nonetheless opened by the effective pressure working on area 40A at the underside of restriction 40K of the relief valve exceeding that above, but the only discharge through line H2 at this time is the small amount of fluid trapped in line H1 between passage 35A (now closed) and the cylinder. Any leaks in the spool valve 35 are bled through line H6, preventing pressure build-up in the end cavity which would negate the differences in areas of the piston 47 and the spool 36.

FIG. 2 is a simplified version of the system in that relief valve 20 is eliminated, solenoid valve 22 is eliminated, and the details of the pressure control valve 25 are not shown. FIG. 2 presents symbology pertinent to a further understanding of operation.

Thus in FIG. 2 $P_s$ is the charge presented by the accumulator 10. At "vent" command (no work required) the seat 31 of valve 25 is relatively wide open, causing the pressure $P_c$ in line H3 to be at a minimum. Spring 37 is fully effective on the spool 36, opening $P_w$ (pressure in line H1) to the tank through passageway 35B and line H6, thereby draining that side of line H1, dispensing with the need for the relief valve.

Upon receiving a "pressure increase" command, poppet 30 closes on seat 31, or closes somewhat sufficiently to increase $P_c$ depending upon the severity of the brake command, or other analog signal representing the required pressure. Thus it will be seen that the pressure in line H4 is monitored by valve 25, and it will be further recognized that line H4 constitutes a pilot control for one end of spool 36. When the seat 31 is restricted or closed more so than shown, pressure builds up in the pilot line H4, shifting spool 36 against spring 37. This opens passage 35A to $P_s$, whereby $P_w$ is increased as the working pressure to be delivered to the work performing means such as the cylinder of a press.

An analog of the working pressure $P_w$ is fed back from the working side of line H1 to valve 35 through the restriction 50 in line H5 tending to cause the spool 36 to close passage 35A. The proportioning is such that the spool will so close 35A when the analog pressure in chamber 45 is at a value dictated by the setting of the pressure control valve.

Referring to FIG. 3, this is a section showing the preferred construction concerned with the manufacture of the flow limiter valve 35 and related connections intended for the arrangement described in connection with FIG. 1, embodied in four parts, 61, 62, 63 and 64 joined together by suitable bolts as 66.

The line (H1) from the accumulator is connected to port 67 in part 61, and another port 69 formed in the same part communicates the accumulator pressure to line H3 which leads to the pressure control valve 25. The restriction 22A may be conveniently located as shown.

Part 62 is provided with a port 70 adapted to be connected to line H1 which leads to the relief valve (20). Port 71 in section 63 leads to the tank (line H6).

When the pressure control valve 25 commands a minimum of vent pressure, spring 37 maintains spool 36 in its normal position preventing flow between ports 68 and 70. The only flow occurring under this condition is the quiescent flow through port 67 and the leakage across the lands of the spool. When the pressure control valve calls for the delivery of working pressure, pressure in port 69 rises as described above, and the pressure (times) area force applied to the head 36–1 of the spool 36 (through line H4) overcomes the force of spring 37, shifting the spool so as to communicate port 68 with port 70. This communication occurs through the reduced center part 36R of spool 36 which moves to the right as viewed in FIG. 3 to bridge the inner ends of the ports 68 and 70.

Working pressure thus established in port 70 is fed through orifice 75 (which corresponds to the restriction 50, FIG. 1) to the chamber 45 behind the push piston 47, tending to return the spool to its original position.

The amount of opening between ports 68 and 70 allowed by the reduced section 36R of the spool in communication therewith is proportional to the difference between the command pressure prevailing in port 69 and the actual working pressure prevailing at port 70. When the working pressure at port 70 equals the command pressure at port 69, the pressure in line H5 working on the push piston 47 in conjunction with the force of spring 37 shifts the spool rendering ports 68 and 70 non-communicative and the spool is nominally closed thus preventing further flow.

It will be seen from the foregoing that the present invention presents an unusual flow control valve 35 in that when the pilot operating pressure in line H4, communicating with the enlargement at one end of the spool 36, is effective to overcome the force of spring 37, thereby shifting the spool to a valve open position, conditions are established at the same time for eventually reversing or closing the valve in that pressure concurrently builds up in the other pilot line H5 acting on the push piston 47 in opposition to the pilot command pressure in line H4. The closing pressure is actually controlled or determined by the pressure control valve and is infinitely variable through its pressure range. Thus, the pressure prevailing

in line H4 may be varied or controlled in many different ways, and the effective size of the passage 35A will actually depend upon the intensity of $P_c$ itself determined by the extent to which the valve seat 31 of the pressure control valve is opened more or restricted more. In essence, the requirements include, besides the unusual flow limiter 35 receiving "back pressure" from line H5, a variable orifice presented by a pressure control valve (e.g. valve 25) downstream of the pilot line H4 and a fixed orifice 22A in upstream relation.

In any event the proportioning of the parameters related to the second pilot line H5, opposing H4, is such that when the pressure in the pilot control chamber 45 is at a predetermined value the spool 36 is shifted to its closed position in opposition to the pressure prevailing in pilot line H4. These parameters, measured in terms of the pressure prevailing in pilot line H4, include the force of spring 37, the exposed areas of the piston 47 in chamber 45, the area of the spool presented by spool head 36–1, FIG. 3, and, in terms of rapidness or response, the size of the narrow opening presented by the restriction 50 or 75 in pilot line H5.

The pilot control line H5 may be connected to the supply line H1 at any point between the flow control valve 35 and the work performing means.

The relief valve itself, when present, is preferably controlled by pressure in pilot line H3A connected to the pressure control valve 25 which is interposed in the control line H3 between the accumulator and the tank or reservoir.

In the ideal system shown, FIG. 1, the accumulator is further conserved by a second flow control valve 22 which is normally closed while the pressure control valve is normally open, and vice versa. Thus, when valve 25 is fully open to bleed line H3, valve 22 is fully closed to conserve the accumulator. The restriction 22A may be on either side of valve 22 so long as it is upstream of the connection of pilot line H4 to conduit or line H3 as already noted. This restriction establishes quiescent flow when valve 22 is open and valve 25 is being vented. Thus, the flow in pilot line H4 is provided by the same source (e.g. the accumulator) which supplies fluid under pressure to actuate the work performing means, and this is made possible by locating the fixed restriction as 22A between the source and pilot line H4 while varying the downstream restriction represented by the pressure control valve, which is to say that without the upstream restriction the variable restriction downstream could not effectively modulate pilot line H4 in the system of FIG. 1.

It may be further explained in connection with the relief valve 20 that its pilot line H3A, connected to the pressure relief valve 25, is effective to modulate the pressure at which the fluid in the supply line H1 will be vented to tank when the relief valve is opened just at the time the primary flow control valve 35 is closed. The area differences already noted, prevailing on opposite sides of the restriction 40K in the relief valve, are responsible for the poppet 39 being normally closed, although closure may be assisted by the spring 42. The closed condition prevails until the pilot pressure flow through the orifice 40K establishes sufficient pressure drop to unbalance the force, opening the poppet, as explained above. Nonetheless the primary flow limiter valve 35 will operate as described with any relief valve which presents a fixed orifice as 40K in conjuction with a variable orifice (that of the pressure control valve) modulating a pilot line H3A controlling the relief valve.

Hence while I have illustrated and described several embodiments of the invention it is to be understood that these are capable of variation and modification by way of equivalents.

I claim:

1. In an hydraulic system having a source for supplying fluid under pressure to a cylinder or other work performing means actuated by fluid under pressure, a supply line for fluid under pressure between the source and the work performing means, a pressure control valve connected by a control line to the source and presenting a variable restriction, a fixed restriction in said control line, a normally closed pilot-operated primary flow control valve of the spool type interposed in the supply line between the source and the work performing means, a first pilot line connected at one end to the control line between said fixed restriction and said pressure control valve and connected at its other end to the flow control valve for delivering a valve-open demand signal to the flow control valve represented by fluid under pressure to move the spool to a valve open position in the supply line placing the source in communication with the work performing means, a second pilot line connected to the opposite end of the flow control valve to deliver fluid under pressure thereto tending to close the flow control valve, said second pilot line being connected to the supply line between the primary flow control valve and the work performing means for receiving fluid under pressure proportional to the pressure in the supply line, the proportioning being such that when the pressure in the second pilot line reaches a value determined by the pressure in the first pilot line the spool is shifted toward its closed position, a relief valve in the supply line between the work performing means and said primary flow control valve, the relief valve being normally closed and in its normally closed position allowing flow of fluid under pressure from the source to the work performing means, a pilot line between the pressure control valve and the relief valve modulating the pressure at which the fluid in the supply line, delivered to the work performing means, is vented to tank and by which the relief valve is allowed to open to reduce the pressure between the primary flow control valve and the work performing means when the primary flow control valve closes.

2. A system according to claim 1 in which there is a normally closed flow control valve in the control line leading from the source to the pressure control valve, and means to close the pressure control valve and concurrently to open the second-named flow control valve when fluid under pressure is to be supplied to the work performing means from the source.

3. A system according to claim 1 wherein the primary flow control valve in its closed position discloses a passage for decreasing the pressure in the portion of the supply line between the flow control valve and the work performing means.

* * * * *