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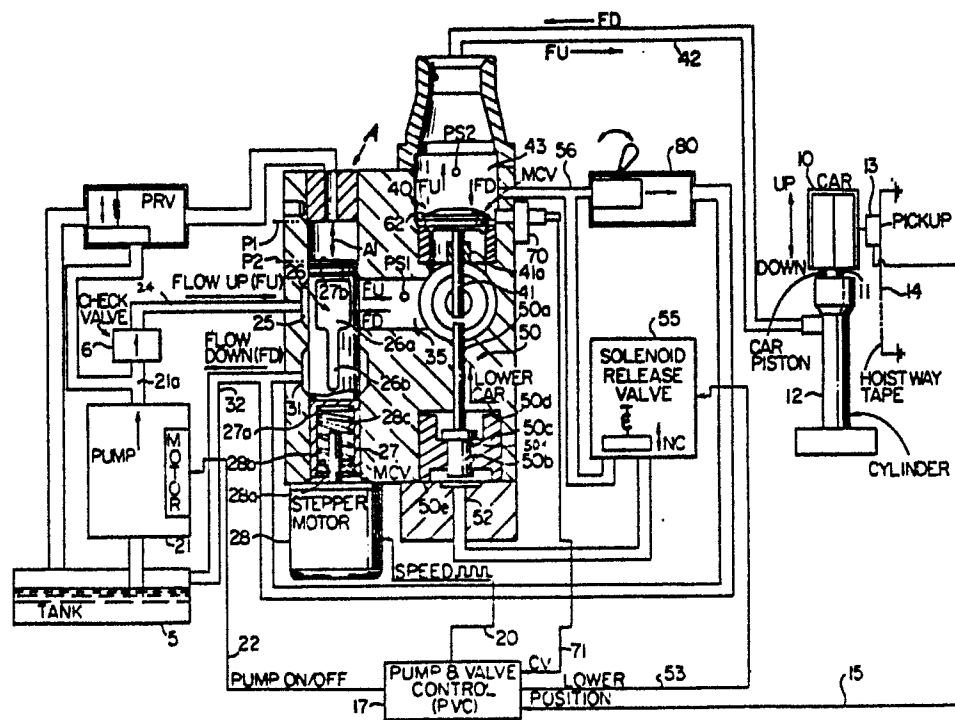
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 **Pressure-referenced programmed flow control in a hydraulic valve.**

 The point at which pump out pressure exceeds load is sensed to provide a point for scheduling flow to an actuator in a hydraulic system, such as an elevator. Flow is controlled by a stepper motor (28) that moves a flow control valve (27). When the pump (21) is turned on, the valve (27) is positioned to bypass flow; the bypass flow is then programmably decreased to increase the flow to the actuator. Reverse flow is regulated by the valve (27) to control actuator retraction. Reverse flow is initiated by opening a check valve (40) with an actuator (50) that opens it first to reduce pressure across the valve, then fully. The flow control valve (27) also operates to relieve excess pressure in the system.



Pressure-Referenced Programmed Flow
Control in a Hydraulic Valve

Technical Field

5 This invention concerns hydraulic valve control systems and is particularly, though not exclusively, useful in hydraulic elevators.

Background Art

10 In an attempt to control a hydraulic elevator with precision approximating the more sophisticated and usually more expensive traction elevators, feedback control is used. But, even using feedback control, comparable performance has been difficult to achieve, and the main problem is the dynamic characteristics of the fluid. Its viscosity shifts with
15 the ambient temperature and also from the heating that occurs as the elevator car is raised and lowered. These variables produce some measure of unpredictability in the motion of the elevator car.
20 The different levels of feedback that have been utilized are typically expensive and require excess pump capacity, which increases the cost and lowers system efficiency.

25 A technique illustrating feedback is shown in U.S. Patent 4,205,592, where the flow through the valve and to an object, such as a hydraulic elevator, is passed through a flow meter that includes a potentiometer. As the flow increases, the output voltage associated with the motion of the potentiometer wiper changes, manifesting the magnitude of the
30 flow. U.S. Patent 4,381,699 shows a similar type of valve control.

U.S. Patent 4,418,794 is illustrative of the type of valve that may be used in systems that do not sense the fluid flow but, using a larger feedback loop, perhaps sense the position of the elevator car and control the operation of the valve.

Disclosure of Invention

Although the invention described herein was made in connection with hydraulic valve controls in elevators and is described, for convenience, in that context, the invention may be useful in other systems having similar control requirements.

According to the present invention, a linear flow control valve is operated by a stepper motor to control flow between the pump and the hydraulic cylinder when the object, e.g., elevator car, is raised and the return flow from the cylinder to the tank when the car is lowered. The time-related motion of this valve mirrors the flow to the car, thus also the car's velocity profile. The operation of the valve begins by placing it in a position at which the fluid from the pump is completely bypassed from the car. The valve is then progressively closed, decreasing that bypass flow. When the pressure applied to the elevator car exceeds the pressure required to sustain the car, motion of the valve is programmed to the desired elevator velocity profile.

According to the invention, the pressure differential that arises when the output pump pressure just exceeds the pressure required to hold the car in place is sensed from the motion of a check valve across which the pump pressure and car pressure are oppositely applied. Movement of the check valve to an open position at which the car will just about start to move is detected by an electrical switch

that produces an electrical control signal that is applied to the main valve control. That control signal acts as the starting point for main valve programmed positioning that determines the velocity
5 profile of the elevator car when the car is moved up.

According to the invention, the connection between the motor and the valve is through a resilient coupling, such as a spring. This connection allows the valve to be moved to bypass
10 fluid flow from the pump back to the tank when the valve is in a position in which all the pump output is directed by the valve to the actuator. A pressure release valve is operated when the pump pressure exceeds a certain level, and that operation applies
15 fluid under pressure to the valve, which, in response, moves against the resilient coupling to connect the pump output to the tank. This valve operation relieves the pump pressure.

There are many features to the present invention.
20 Most significant, it provides very precise performance because the fluid and load characteristics may control the operation of the valve. Yet, it is simple and reliable because feedback is used selectively to adjust for those characteristics. For
25 the most part, the valve flow is controlled without feedback.

Brief Description of the Drawing

The drawing is a schematic view showing by way of example only a hydraulic elevator control system embodying the present invention.

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Fig. 1 shows a hydraulic elevator control system for moving an elevator car 10 between a plurality of floors or landings. The floors or landings are not shown. The car is attached to a car piston (plunger) 11 that extends from a cylinder 12, and fluid is pumped into or discharged from the cylinder to raise and lower the car respectively, that flow being controlled and regulated in a manner that will be described in detail. The motion of the car is detected by a pickup 13. Associated with a stationary position tape 14, the pickup provides a signal (POSITION) on line 15, that is supplied to a pump and valve control (PVC) 17. The POSITION signal manifests the car position and velocity. The position of the car thus sensed is used for controlling the flow of fluid to and from the cylinder, controlling the position of the car piston or plunger 11. The PVC 17 controls a hydraulic valve system that includes a pump 21 and a fluid reservoir (tank) 5. The pump supplies fluid to a hydraulic control valve assembly A through a check valve 6 (to prevent back flow), and this assembly is controlled, along with the pump, by the PVC 17. The pump is turned on or off (activated/deactivated) by a pump on/off signal on a line 22, and the fluid from the pump is applied under pressure through the check valve 6 to a first port 25.

The port 25 leads to a "key-shaped" valve window 26 that is part of a linear valve 27, one that moves back and forth linearly between two positions P1, P2.

The position of the valve 27 is controlled by a
stepper motor 28 which receives a signal (SPEED) on
the line 20 from the PVC 17. That signal comprises
successive pulses, and the frequency of those pulses
5 determines the motor's 28 speed; hence also the
longitudinal (see arrow A1) rate of positioning of
the valve 27. Each pulse in the SPEED signal
represents an incremental distance along the length
of motion of the valve 27 between points P1 and P2.
10 The position (location) of the valve is represented
by the accumulated count between those positions.
The valve window 26 comprises a large window 26a and
an adjacent narrower window 26b, giving it a "key-
shaped" appearance. At one point, P2, the large
15 window 26a is adjacent the first inlet port 25, and
the narrower adjacent portion 26b is located next to
a second port 31. At this point, the valve 27 is
"open". That second port 31 leads to a line 32 that
goes to the tank 5. At position P1, the small window
20 26b is mostly adjacent to the port 25, and the path
to the port 31 is blocked by the solid part of the
valve. At that position, the valve 27 is "closed".
In the open position, at P2, fluid flows from the
pump through the line 24; this is "flow-up" (FU),
25 flow to raise the car. The fluid then passes into
the large window 26a and, from there, through the
small window 26b back to the line 32, then to the
tank. The FU flow is thus bypassed when the pump is
started. But, as the valve 27 closes (moves to posi-
30 tion P1), the pressure of the FU fluid flow begins to
build in an internal port 35, while the bypass flow
on line 32 decreases as the path through window 26b
to port 31 decreases. As the valve 27 moves to
position P1 (nonbypass position), there is some
35 overlap of the two windows 26a, 26b and the main
inlet port 25, meaning that the path through the

large window 26a decreases, while the path through the smaller window 26b increases. But, the area of the smaller window 26b is more dependent than with the case of the larger window on the longitudinal position of the valve 27. As a result of this, the change in flow is controlled by the smaller valve window area to outlet port 31, which reduces as the main valve begins to move towards the closed position at P1, at which all the FU flow passes from the port 25 to the inlet 35; there being no path between the port 25 and the outlet port 31.

The fluid pressure PS1 in the internal port 35 is applied to a main check valve (MCV) 40. This valve has a small stem 41 that rests in a guide 41a. The MCV may freely move up and down in response to the pressure differentials between the port 35 and the port 43, where the pressures are PS1 and PS2, respectively. When the pump is turned on and the main valve 27 closes, moves towards position P1, the MCV 40 is pushed upward when PS1 exceeds PS2, allowing the FU flow to pass through the MCV into the line 42 that extends to the cylinder 12. This happens as the bypass flow decreases. The resultant fluid flow displaces the car piston 11 upward, moving the car in the same direction.

When the car 10 is at rest, pressure in the line 42 and the pressure in the chamber 43 are the same, pressure PS2. With the pump 21 off, this pressure pushes the MCV 40 down, and the down flow (FD) in the line 42 is then blocked, holding the car 10 in position. No flow through the line 42 and back to the tank 5 is possible under this condition. To allow this flow to occur, the MCV 40 must be lifted, and this is effected by the operation of a main check valve actuator 50.

5 This actuator includes a rod 50a, which contacts
the stem 41 when pushed upward; a first member 50b
which is pushed upward against the rod; a second
member 50c which when pushed upward moves the first
10 member. The rod 50a is thrust upward, pushing the
MCV 40 upward, when fluid, at pressure PS2, is
applied to the inlet line 52, and that happens only
when a LOWER signal is applied to the line 53 that
goes to a solenoid control release valve 55. The
15 fluid pressure in the line 52 is then applied to the
bottom of the members (pistons) 50b, 50c. The
combined surface area of those members is greater
than the upper surface area 62 of the valve 40. The
second member moves until it strikes the wall 50d of
20 the chamber 50e. The first member also moves with
the second member because of the flange 50f. This
small motion (as far as the wall 50d) "cracks" open
the MCV 40, equalizing the pressures PS1 and PS2.
Then the first member continues to move upward, until
it too strikes the wall, fully opening the MCV 40.
This allows return flow (FD) from the chamber 35
that passes through the windows 26a, 26b, and line
32. The FD flow through line 25 is blocked by the
check valve 6. The position of the valve 27
25 determines the rate of the FD flow, thus the speed
profile of the car as it descends. The valve is
moved from the closed P1 position by the SPEED signal
towards the open position P2. The duration and
frequency of the SPEED signal sets the down velocity
30 profile.

There is switch 70 that is adjacent the MCV 40,
and the upward motion of the MCV 40 causes the switch
to operate. That operation provides a signal (CV) on
the line 71 going to the PVC 17. The CV signal shows
35 that the valve has moved in the up direction for
elevator travel. It represents that the pressure in

the chamber 35 has slightly exceeded the pressure in the chamber 43. Using this signal, the PVC may control the further motion of the valve spool by controlling the pulse rate and duration comprising the SPEED signal, which is applied to the line 29. The CV signal occurs just when the pressure of PS1 35 exceeds the pressure PS2, and that occurs just before there is actual flow. Generation of the CV signal consequently provides a definitive manifestation of "anticipated" flow.

The stepper motor controlled valve 27 also provides a pressure release function for the port 35. The stepper motor 28 has an output link 28a, and a collar or ring 28b is attached to that link. The link and collar fit in a hollow portion of the valve 27 but separated from the flow area (windows 26a, 26b) by the valve wall 27a, which is opposite another wall 27b. (The valve 27 is shaped like a hollow cylinder; fluid flows through its interior). A spring 28c fits between the wall 27b and the collar 28b. As the stepper motor operates, the link moves up or down, in steps corresponding to the steps in the SPEED signal. As a result of this, the change in flow is controlled by the smaller valve window area to outlet port 31, which reduces as the main valve begins to move towards the closed position at P1, at which all the FU flow passes from the port 25 to the inlet 35; there being no path between the port 25 and the outlet port 31. This link motion is transmitted to the wall 27a through the spring to the valve 27, which moves in synchronism with the link. If the pressure in the pump output line 21a is sufficient to open the pressure release valve (PRV), the pressure is applied to the top of the valve 27b and the entire valve 27 is forced down, allowing the flow from the

pump to pass through the line 32, to the tank 5, to relieve the "overpressure" condition.

For manually lowering the car, a manually operated valve 80 is operated to allow the fluid to
5 flow from the chamber 43 directly back to the tank 5.

The preferred embodiment of the invention has been described, and one of ordinary skill in the art to which the invention relates may make modifications and variations to that embodiment, in whole or part,
10 without departing from the true scope of the invention.

Claims

1. A hydraulic valve (A) comprising:
 - a main inlet (25) adapted for connection to a pump (21);
 - 5 a main outlet (43) adapted for connection to an actuator comprising a piston (11) and a cylinder (12);
 - a secondary outlet (31) adapted for connection to a fluid tank (5);
 - 10 a flow control valve (27) for controlling fluid flow from the main inlet to the main outlet; the hydraulic valve (A) being characterized by:
 - 15 the flow control valve being continuously movable between two positions to control progressively, from a minimum to a maximum equalling the pump output, the flow between the main inlet and the main outlet or discharge from the main outlet to the tank, at one position the main inlet and secondary
 - 20 outlet being connected, at the other position the main inlet and the main outlet being connected and the main inlet and secondary outlet being disconnected;
 - a motor (28) for moving the valve linearly
 - 25 in discrete steps;
 - a resilient member (28c) interconnecting the motor and the valve;
 - the motor applying force through the resilient member to move the valve to said one
 - 30 position and to hold the valve in any position against the pressure on the valve by the fluid in the main outlet from the main outlet; and
 - a pressure operated valve (PRV) connected to the pump output and the flow control valve (27);

the flow control valve being movable against the force of the resilient member towards said one position in response to fluid applied thereto by the pressure operated valve when the pump output pressure exceeds
5 a certain level.

2. A valve (A) according to claim 1, characterized by:

the flow control valve (27) comprising a hollow cylinder with windows (26a, 26b) through which fluid
10 enters and leaves the interior of the cylinder, said resilient member being disposed between the motor and one end of the cylinder, and the other, opposite end of the cylinder being located in a chamber connected to the pressure operated valve.

15 3. A hydraulic valve (A) comprising:

a main inlet (25) adapted for connection to a pump (21);

a main outlet (43) adapted for connection to an actuator comprising a piston (11) and a cylinder
20 (12);

a secondary outlet (31) adapted for connection to a fluid tank;

a flow control valve (27) for controlling fluid flow from the main inlet (25) to the main
25 outlet (43);

the hydraulic valve (A) being characterized by:

a check valve (MCV) with its inlet (35) connected to the flow control valve (27) and its
30 outlet connected to the main outlet (43), the check valve being operable to open and connect its inlet and outlet when the pressure in the inlet exceeds the

pressure in the outlet and also being mechanically operable to open;

a switch (70) that is actuated by the check valve when it opens and closes; and

5 the flow control valve being continuously movable between two positions to control, from a minimum flow to a maximum flow equalling the pump output, the flow between the main inlet and the main outlet through the check valve and to control the
10 discharge flow from the main outlet to the tank.

4. A valve according to claim 3, further characterized by:

a hydraulic actuator (50) that moves to open the check valve;

15 a solenoid valve (55) operable for connecting the actuator with the main outlet.

5. A valve according to claim 4, characterized in that the actuator comprises:

a first pressure responsive member (50c) and
20 a second pressure responsive member (50b) that can move simultaneously for a first distance to slightly open the valve, the second member (50b) being additionally movable beyond that first distance to open the valve further, the combined surface area of
25 the two members being greater than the area of the check valve, so that the force of the two members exceeds the opposing force of the valve caused by the main outlet (43) pressure.

6. A valve according to claim 3, 4 or 5
30 further characterized by:

a stepper motor (28); and

the flow control valve (27) being a linear motion valve, and the stepper motor being connected to the valve for moving it linearly in finite steps in response to a stepper signal, the stepper signal
5 comprising variable frequency pulses.

7. A valve according to any of claims 3 to 6, further characterized by:

the flow control valve (27) being a hollow cylinder that contains a first pair of diametrically-
10 opposed windows (26a) and adjacent thereto a second pair of diametrically-opposed windows (26b) for controlling the flow from the main inlet;

the flow through area of the first pair of windows from the main inlet increasing more for each
15 unit of movement by the flow control valve than the flow through area from the main inlet through the second pair of windows.

8. A hydraulic control system comprising:

a hydraulic actuator (11,12);
20 a pump (21);
a tank (5), and a valve (A) for controlling flow between the tank and the actuator with the pump, comprising:

a main inlet (25) adapted for connection to
25 a pump (21);

a main outlet (43) adapted for connection to the actuator;

a secondary outlet (31) adapted for connection to the tank;

30 a flow control valve (27) for controlling fluid flow from the main inlet (25) to the main outlet (43);

characterized by the valve (A) comprising:
a check valve (MCV) with its inlet (35)
connected to the flow control valve (27) and its
outlet connected to the main outlet (43), the check
5 valve being operable to open and connect its inlet
and outlet when the pressure in the inlet exceeds the
pressure in the outlet and also being mechanically
operable to open;
a switch (70) that is actuated by the check
10 valve when it opens and closes;
the flow control valve being continuously
movable between two positions to control, from a
minimum flow to a maximum flow equalling the pump
output, the flow between the main inlet and the main
15 outlet through the check valve and to control the
discharge flow from the main outlet to the tank, and
by:
a motor (28) to move the flow control valve;
and
20 means (17) for controlling the operation of
the motor in response to an electrical signal
produced by operation of said switch.

