

May 18, 1937.

J. K. DOUGLAS

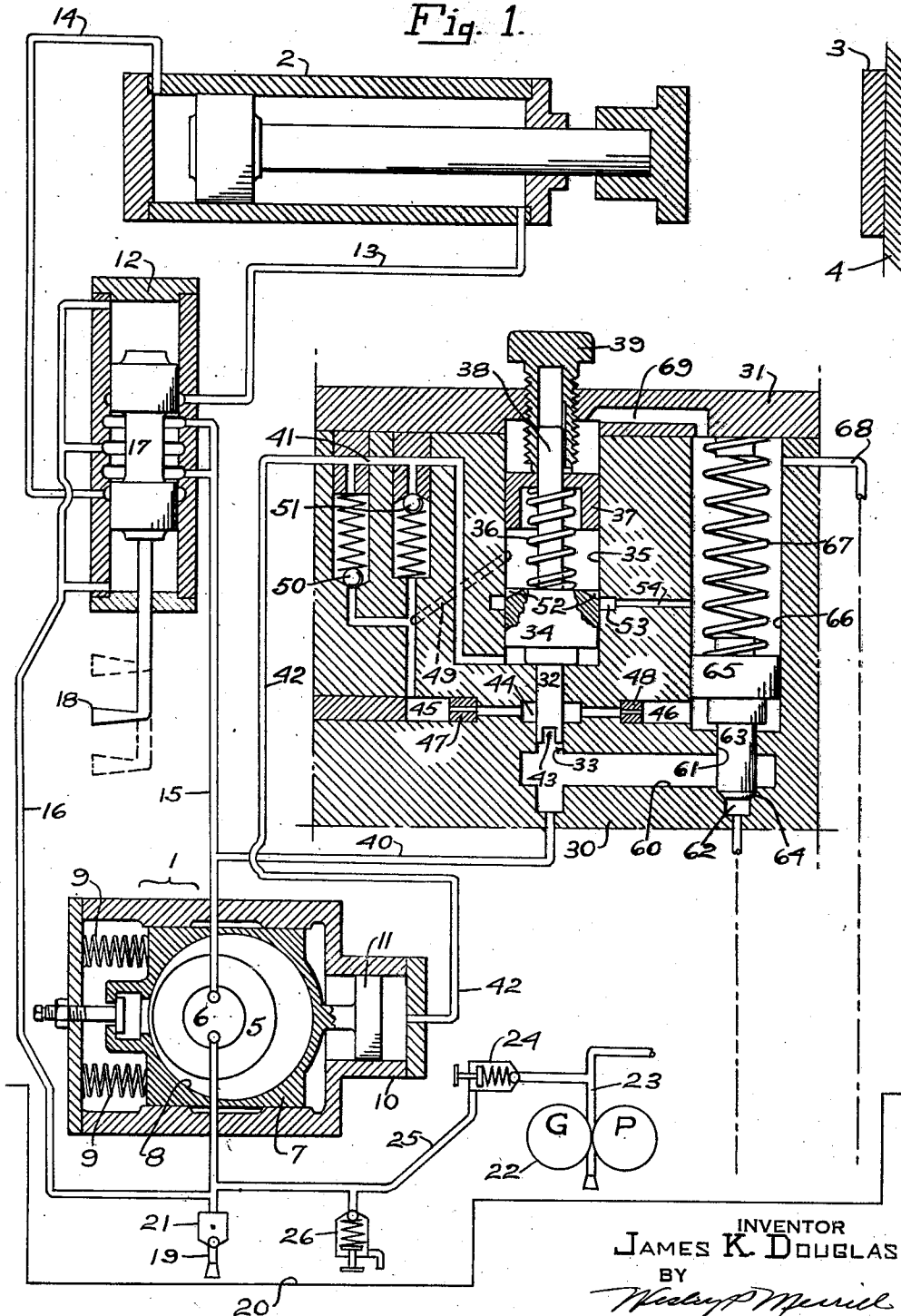
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PUMP CONTROL

Filed June 24, 1935

2 Sheets-Sheet 1

Fig. 1.



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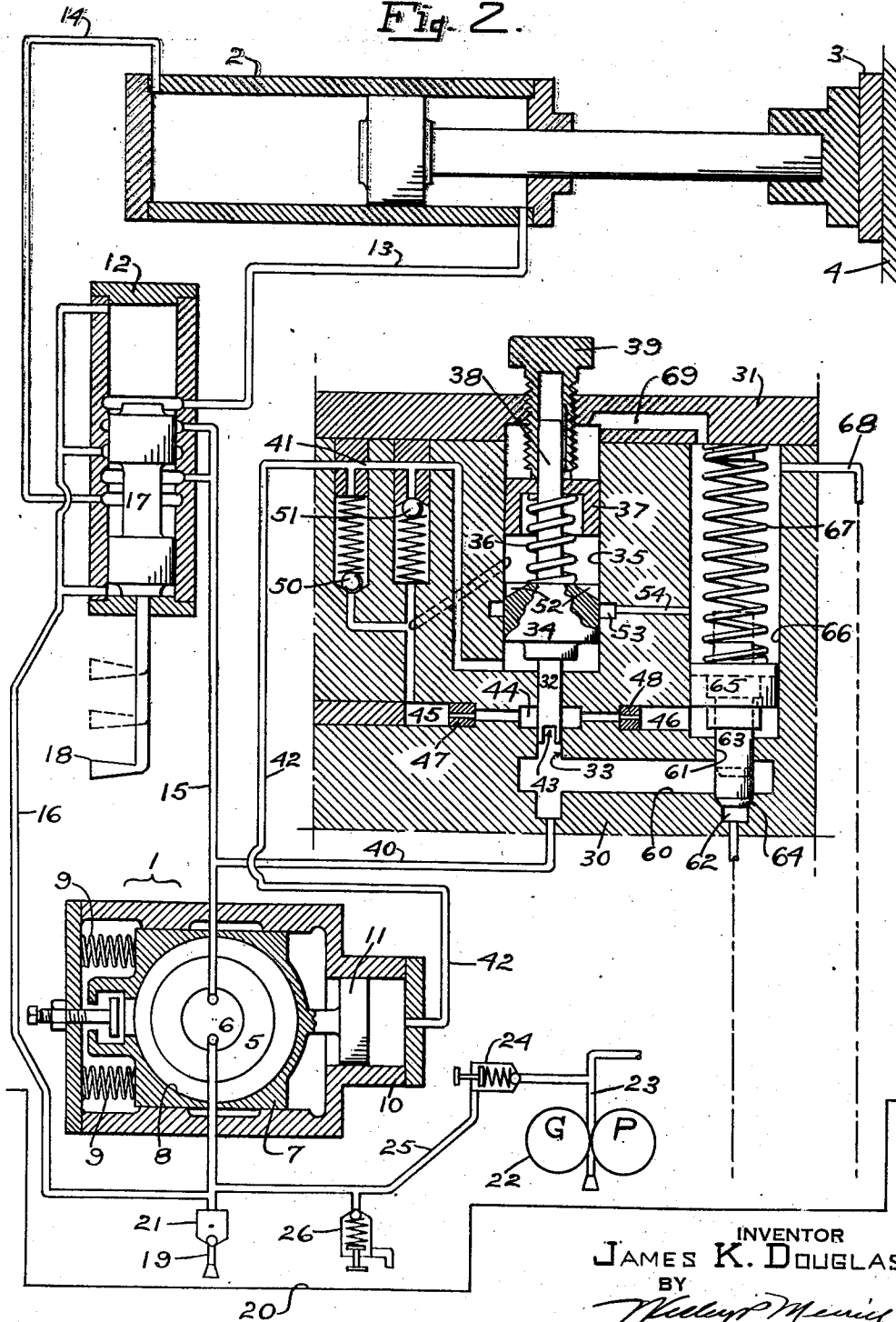
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2 Sheets-Sheet 2

Fig. 2.



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PUMP CONTROL

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Application June 24, 1935, Serial No. 28,068

20 Claims. (Cl. 103—38)

This invention relates to pump controls of the type which enable a variable displacement pump to function either as a variable delivery pump or as a constant delivery pump until pump pressure reaches a predetermined maximum and then function as a constant pressure pump, such as the control disclosed in Patent No. 2,009,608 granted to me on application Serial No. 547,268, filed June 27, 1931, of which this application is a continuation as to matters common to both applications.

Prior to the pump control disclosed in the above patent, the constant pressure pump controls in most common use were provided with a spring for urging the stroke-changing mechanism of the pump toward full stroke position and a fluid motor acting in opposition to the spring to move the stroke-changing mechanism toward zero stroke position, such as the pump control disclosed in Patent No. 1,578,233 issued March 23, 1926 to Walter Ferris.

The stroke control motor was ordinarily open at all times to pump pressure and the spring had to have its tension so adjusted that it would hold the stroke-changing mechanism stationary until the pressure created by the pump exceeded the predetermined maximum and then yield to allow the motor to reduce the stroke of the pump. However, as the resistance of a spring increases as it is deflected, pressure in excess of the predetermined maximum was required to compress the spring sufficiently to reduce the pump stroke to substantially zero.

As the maximum pump pressure is often high and as the resistance of a spring increases according to the amount it is deflected, a small diameter control motor and a long flexible spring were employed but it was found that, if the pump operated at approximately full stroke at lower pressures and its stroke had to be reduced nearly to zero to maintain constant a predetermined maximum pressure, there was a great difference between that predetermined maximum pressure and the pressure at which the control started to reduce pump displacement.

If the pump is of the type in which the pump pistons react against a circular reaction surface formed in a slide block which is shifted to vary pump displacement, the action of the pistons produce a force which tends to move the slide block to its zero stroke position. This force is very strong when the pump is at full stroke and disappears when the stroke is reduced to zero. Consequently, the force required to hold a pump at a given stroke will vary according to the length

of stroke and thereby cause pump pressure to be different at different lengths of stroke.

Also the friction of the slide block or other stroke-changing element adds to pump pressure when pump displacement is being reduced and lowers it when pump displacement is being increased.

The control shown in Patent No. 2,009,608 overcomes the above difficulties by interposing a pressure-operated control valve between the discharge side of the pump and the hydraulic servo-motor which operates the stroke-changing mechanism of the pump. The control valve prevents liquid from the pump from entering the servo-motor until pump pressure reaches a predetermined value and then it throttles the flow and thereby causes the liquid to enter the servo-motor at a low pressure.

The control functions quite accurately to prevent pump pressure from exceeding the predetermined maximum. However, the control valve has a certain amount of frictional resistance which must be overcome by the fluid pressure when the valve is shifted in the direction to decrease pump displacement and by the valve spring when the valve is shifted in the direction to increase pump displacement. Therefore, after pump displacement has been reduced in response to pump pressure reaching a predetermined maximum, pump pressure must fall below that predetermined maximum by an amount proportional to the frictional resistance of the valve before the valve can close, thereby causing the stroke-changing mechanism to hunt under certain conditions of operation.

The pump pressure will thus be maintained constant if the load on the pump remains constant or if it continues to increase above the value at which the pump develops the predetermined maximum pressure. If the load on the pump fluctuates above and below that value, the control will keep the pump pressure within a narrow range but it will hunt.

Also, if the motor driven by the pump should stall instantaneously, the inertia of the stroke-changing mechanism would prevent the stroke of the pump from being instantly reduced to zero with the result that pump pressure would rise momentarily.

The present invention has as an object to produce a pump control which will be free of the above mentioned objectionable characteristics.

Another object is to provide a pump control which is positive and precise in operation.

Another object is to provide a pump control

which will prevent the stroke-changing mechanism of the pump from hunting.

Other objects and advantages will appear from the description hereinafter given of a pump control in which the invention is embodied.

According to the invention in its general aspect and as ordinarily embodied in practice, the delivery of liquid to the stroke control motor of the pump is controlled by a control valve which is provided with means for compensating for the frictional resistance to its movement.

According to the invention in another aspect, the valve which controls the delivery of liquid to the stroke control motor also functions as a pilot valve for a relief valve through which liquid discharged by the pump may pass in response to pump pressure suddenly increasing above a predetermined maximum.

The invention is exemplified by the pump control shown diagrammatically in the accompanying drawings in which the views are as follows:

Fig. 1 is a circuit diagram of a hydraulic transmission to which the invention has been applied, the pump being shown at full stroke and the control valve and the relief valve being shown closed.

Fig. 2 is a view similar to Fig. 1 but showing the control valve in its operative position and the pump at short stroke.

For the purpose of illustration, the invention is shown applied to a hydraulic transmission consisting of a variable displacement pump 1 and a reciprocating hydraulic motor 2 which may be employed for pressing a work piece 3 against an abutment 4.

The pump chosen for illustration is of the rolling piston type fully described in Patent No. 1,998,984. It is sufficient to state that the pump has its cylinders and pistons arranged radially in a cylinder barrel 5 which rotates upon a central valve shaft or pintle 6 through which liquid flows to and from the cylinders.

The cylinder barrel 5 is arranged inside a thrust member or slide block 7 having an inner circular reaction surface 8 which engages the outer ends or heads of the pistons and causes the pistons to reciprocate in the cylinders whenever the cylinder barrel is rotated and the axis of the reaction surface 8 is offset from the axis of the cylinder barrel 5. The stroke of the pistons and consequently the volumetric delivery of the pump is proportional to the distance that the axis of the reaction surface is offset from the axis of the cylinder barrel.

In the patent, the pump is shown provided with a hand-operated screw for shifting the slide block to thereby change pump displacement. In the present instance, the slide block 7 is urged toward the right to increase pump displacement by two helical compression springs 9 and toward the left to decrease pump displacement by a hydraulic servo-motor consisting of a stationary cylinder 10 and a piston 11 which is fitted in the cylinder 10 and connected to the slide block.

Delivery of liquid from the pump 1 to the motor 2 is controlled by a reversing valve 12 which has its casing connected to opposite ends of the motor 2 by two pipes 13 and 14, to the discharge port of the pump 1 by a high pressure pipe 15 and to the return port of the pump 1 by a return pipe 16.

The flow of liquid through the valve 12 is controlled by its plunger 17 which is shown provided with a handle 18 for manual operation thereof. When the plunger 17 is in its central position as

shown in Fig. 1, pipe 15 is open to pipe 16 so that the pump is bypassed and the motor 2 is idle.

When the plunger 17 is in its lower position as shown in Fig. 2, pipe 15 is open to pipe 14 and liquid delivered by the pump will enter the head end of the motor 2 and advance its piston on a working stroke, liquid exhausted from the rod end of the motor being returned to the pump through pipes 13 and 16. When the handle 18 is shifted to its upper position as shown in dotted lines, the valve plunger 17 will be in its uppermost position and pipe 15 will be open to pipe 13 and pipe 14 will be open to pipe 16 so that the pump will deliver liquid to the rod end of the motor 2 to retract its piston and liquid discharge from the head end of the motor 2 will be returned to the pump through pipes 14 and 16.

Since the volume of liquid delivered by the pump 1 to the head end of the motor 2 to advance the motor piston on a working stroke is considerably in excess of the volume returned to the pump from the rod end of the motor, means must be provided for supplying the pump with that excess volume during the working stroke and for permitting the escape of an equal volume during the return stroke.

As shown, the return pipe 16 is connected to a suction pipe 19 which extends into a reservoir 20 and has a check valve 21 connected therein which permits the pump to draw liquid from the reservoir but prevents liquid from being discharged through the suction pipe into the reservoir, and a gear pump 22 draws liquid from the reservoir 20 and discharges it into a low pressure supply pipe 23 which is connected to the return pipe 16 through a resistance valve 24 and a pipe 25 having a low pressure relief valve 26 connected thereto and discharging into the reservoir 20.

The output of the gear pump 22 is ordinarily employed for control purposes, such as operating the reversing valve 12, and for supplying liquid to the pump 1. Liquid discharged by the gear pump in excess of these requirements is exhausted into the reservoir 20 through the relief valve 26 so that the pressure in the supply pipe 23 is equal to the sum of the resistances of the valves 24 and 26 and the pressure in the pipe 25 is equal to the resistance of the relief valve 26.

If, during the working stroke of the motor 2, the volume required to be supplied to the pump 1 from the reservoir 20 is in excess of the volumetric capacity of the gear pump 22, the pump 1 will draw liquid from the reservoir through the suction pipe 19 and check valve 21. During the return stroke of the motor 2, the liquid discharged from the head end thereof in excess of the volume required by the pump 1 will be exhausted through the low pressure relief valve 26.

Liquid for operating the stroke control motor 10-11 is supplied thereto from the high pressure pipe 15 through a control unit shown as having its mechanism arranged within a casing 30 which is closed at its top by a cover plate 31.

The casing 30 contains a control valve 32 which is closely fitted in a bore 33 and has fixed thereto a piston 34 which is larger in diameter and closely fitted in a counterbore 35 formed in the casing 30 concentric with the bore 33.

The valve 32 is urged downward into its closed position by a helical compression spring 36 which has one of its ends in contact with the upper face of the piston 34 and its other end in contact with a bushing 37 which is closely fitted in the counterbore 35 and closely fitted around a stem 38 which is secured to or formed integral with the

piston 34 and is of the same diameter as the valve 32 so that the upper and lower faces of the piston 34 will have equal pressure areas.

The stem 38 extends upward through the spring 36 and the bushing 37 into a hollow adjusting screw 39 which is threaded through the cover plate 31 into contact with the bushing 37 and which may be rotated to adjust the tension of the spring 36.

Any liquid which may seep past the bushing 37 into the upper end of the counterbore 35 or into the interior of the adjusting screw 39 may escape therefrom through suitable drain channels.

The lower end of the bore 33 is connected to the high pressure pipe 15 by a pipe 40, and the lower end of the counterbore 35 is connected to the control cylinder 10 by a passage 41 and a pipe 42 so that the lower face of the piston 34 is exposed at all times to the pressure prevailing in the control cylinder 10 and the lower end of the valve 32 is exposed at all times to pump pressure.

The pressure acting on the valve 32 tends to raise it against the resistance of the spring 36 which is adjusted to keep the valve closed until pump pressure reaches a predetermined maximum.

The valve 32 is provided at its lower end with one or more notches or slots 43 which, when the valve is raised in response to a predetermined high pump pressure, will communicate with an annular port 44 formed in the wall of the bore 33. The port 44 is connected at one side to a passage 45 and at the other side to a passage 46 which ordinarily have chokes 47 and 48 arranged therein, respectively, to restrict the flow of liquid therethrough.

The function of the choke 48 is to prevent the chattering of a relief valve to be presently described. The function of the choke 47 is to limit the flow of liquid through the passage 45 to thereby limit the rate at which the servo-motor 10—11 is operated and to enable a higher pressure to be built up in the passage 46 when the relief valve is to be operated.

The passage 45 is connected, at a point beyond the choke 47, by a passage 49 to the counterbore 35 at a point between the piston 34 and the bushing 37, and it is connected to the passage 41 through two opposed low pressure resistance valves 50 and 51 which are connected in parallel with each other.

Each of the resistance valves 50 and 51 is so adjusted that the drop in pressure across it is equal to the pressure required to produce the force necessary to overcome the frictional resistance of the control valve 32 and the parts movable therewith, such as the piston 34 and the stem 38.

In order that liquid may escape from the control cylinder 10 when the control valve 32 is closed, the piston 34 is provided around its upper edge with a plurality of small tapered grooves or slots 52 which communicate when the valve 32 is closed with an annular port 53 formed in the wall of the counterbore 35 and connected to a drain channel 54.

The slots 43 and 52 are preferably so arranged that the vertical distance between them is equal to the vertical distance between the lower edge of the port 44 and the upper edge of the port 53 so that, when the control valve has been raised until the bottom of the slot 43 is even with the bottom edge of the port 44, the bottom of the slots 52 will be even with the upper edge of the port 53. Then, a very slight movement of the

control valve 32 in either direction will open either the port 44 to the high pressure pipe 15 or the passage 49 to the drain channel 54.

In order to relieve the pump 1 should pump pressure suddenly rise above a predetermined maximum, the casing 30 is provided with a channel 60 having one of its ends open at all times to pump pressure through the pipe 40 and its other end intersecting a bore 61 formed in the casing 30 and communicating at its lower end with a relief channel 62 which discharges into the reservoir 20.

Communication between the channels 60 and 62 is controlled by a relief valve 63 which is closely fitted in the bore 61, extends across the channel 60 and normally engages an annular valve seat 64 arranged at the lower end of the bore 61 around the relief channel 62.

The relief valve 63 has a piston 65 fixed thereto and closely fitted in a counterbore 66 formed in the casing 30 concentric with the bore 61 and containing a helical compression spring 67 which urges the relief valve 63 downward into engagement with the valve seat 64.

The counterbore 66 is open at its lower end to the passage 46 so that the lower face of the piston 65 is subjected to fluid pressure when the control valve 32 is open. In order that operation of the relief valve may not be impeded by liquid trapped in the counterbore 66 above the piston 65, the upper part of the counterbore 66 is open to the reservoir 20 as by means of a drain pipe 68.

As shown, the drain channel 54 discharges into the counterbore 66 at a point above the piston 65 and the upper end of the counterbore 35 drains into the upper end of the counterbore 66 through a channel 69 formed in the cover plate 31. The drain pipe 68 communicates with the counterbore 66 at a point above the bushing 37 so that the space in the counterbore 35 between the piston 34 and the bushing 37 is kept flooded with liquid. After the counterbore 66 is filled with liquid to the level of the entrance to the pipe 68, all liquid is drained from the counterbore 35 into the counterbore 66 and any liquid which may escape past the piston 65 will drain through the pipe 68 into the reservoir 20.

The pressure responsive pump controls produced prior to the pump control shown in Patent No. 2,009,608 required one adjustment to determine the pressure at which the high pressure relief valve would open and a separate adjustment to determine the pressure at which the stroke control servo-motor would reduce pump displacement. In certain kinds of service, it is important that the relief valve shall open at a pressure not greatly in excess of the pressure at which pump displacement is reduced. A pressure gauge is ordinarily provided so that adjustment of the stroke control mechanism may be readily made by the operator of the machine with which the pump is associated. Adjustment of the relief valve, however, almost invariably proves to be a difficult operation and few, if any, of the operators possess sufficient skill or knowledge to make proper adjustment thereof.

In order that the operator may readily and conveniently regulate both the pressure at which pump displacement is reduced and the pressure at which the relief valve opens, servo-motor 10—11 and servo-motor 65—66 are placed under the control of valve 32 and spring 67 is so ad-

justed at the factory, as by placing shims under an end thereof, that its tension bears a definite relation to the tension of springs 9. Then, the pressure required to operate servo-motor 10—11 and the pressure required to operate servo-motor 65—66 are simultaneously varied by simply turning adjusting screw 39 to vary the tension of spring 36.

Operation

When the pump 1 is delivering liquid at a low pressure, as when the pipe 15 is connected to the return pipe 16 through the reversing valve 12, the control valve 32 and the relief valve 63 will be closed and the springs 9 will be holding the pump at full stroke as shown in Fig. 1.

When pump pressure rises to a predetermined value, as when the motor 2 presses the work 3 against the abutment 4, the liquid acting on the lower end of the control valve 32 will raise the valve 32 against the resistance of the spring 36 until the bottom of the slot 43 is above the lower edge of the port 44 at which time the drain port 53 is closed due to the fact that the slots 52 in the piston 35 are above it.

Raising the control valve 32 permits liquid from the pipe 40 to enter the port 44 and flow therefrom through the passage 45, low pressure resistance valve 50, passage 41 and pipe 42 to the control cylinder 10 and move the piston 11 and the slide block 7 toward the left to reduce the stroke of the pump.

Due to the throttling effect of the valve 32, the liquid enters the port 44 at a very low pressure and, due to the fact that the circuit is always filled with liquid when the transmission is in operation, pressure builds up substantially instantly until it is high enough to overcome the resistance of the springs 9 which are so adjusted that a low pressure, for instance 50 lbs. per sq. in., acting on the piston 11 is sufficient to move the slide block 7 toward the left.

At the same time, pressure extends through the passage 46 to the lower end of the counterbore 66 and acts upon the lower face of the piston 65, through the passages 45 and 49 to the space in the counterbore 35 between the piston 34 and the bushing 37 where it acts upon the upper face of the piston 34, and through the passage 45, resistance valve 50 and passage 41 to the lower end of the counterbore 35 where it acts upon the lower face of the piston 34.

Unless pump pressure should rise suddenly above the predetermined maximum, the pressure acting upon the lower face of the piston 65 will not raise the relief valve 63 for the reason that the spring 67 is so adjusted that the pressure required to open it, for instance 100 lbs. per sq. in., is higher than the pressure required to reduce the stroke of the pump.

The pressure acting on the lower face of the piston 34 is the same as the pressure acting on the piston 11, while the pressure acting on the upper face of the piston 34 is higher due to the drop in pressure across the resistance valve 50 which is so adjusted that the pressure required to open it is equal to the pressure required to exert a force on the piston 34 equal to the frictional resistance of the pilot valve 32 and the parts movable therewith.

The pilot valve 32 is thus urged downward by a spring force which is equal to the force produced by the predetermined maximum pump pressure and by a hydraulic force which is equal to the force required to overcome the frictional

resistance of the valve. Therefore, when pump displacement has been reduced until it is just sufficient to maintain the predetermined maximum pressure constant, the pilot valve 32 will move downward until the bottom of the slot 43 is substantially in alignment with the bottom of the port 44 and the bottom of the slots 52 are substantially in alignment with the top edge of the port 53. More specifically, the valve 32 floats between a position which permits a minute flow of liquid to the control cylinder 11 and a position which permits a minute flow of liquid from the control cylinder 11.

When pump pressure drops below the predetermined maximum, the control valve 32 will move downward and close the port 44 to the pipe 40 and open the passage 49 to the drain port 53. The springs 9 will then move the slide block 7 toward the right to increase pump displacement and the piston 11 will expel liquid from the cylinder 10 through the pipe 42, passage 41, resistance valve 51, passage 49, counterbore 35, slots 52 and port 53 into the drain channel 54.

At this time the pressure acting upon the lower face of the piston 34 is higher than the pressure acting upon the upper face thereof due to the drop in pressure across the resistance valve 51 which is so adjusted that the pressure required to open it is equal to the pressure required to produce the force necessary to just overcome the frictional resistance of the control valve 32 and the parts movable therewith. Therefore, when pump pressure rises, the valve 32 will rise as soon as the pressure reaches the predetermined maximum for the reason that the frictional resistance of the valve 32 is overcome by the pressure acting upon the lower face of the piston 34.

The piston 34 and the counterbore 35 thus constitute an auxiliary servo-motor whose function is to overcome the frictional resistance of the valve which controls the operation of the stroke control motor. By means of this arrangement a predetermined maximum pump pressure may be maintained at substantially an exact value.

In the foregoing explanation of the operation of the pump control, the function of the relief valve 63 has been disregarded. If the pump control is applied to a transmission the motor of which does not stall during normal operation thereof, the relief valve 63 may be omitted or replaced by a conventional relief valve connected direct to the discharge side of the pump.

If the motor of the transmission to which the pump control is applied should suddenly stall, as by the work piece 3 offering more resistance than the motor 2 can overcome, the servo-motor 10—11 could not reduce pump displacement instantly to substantially zero on account of the inertia of the slide block 7. Therefore, the pilot controlled relief valve 63 is provided and the passage 45 is provided with a choke 47 of the correct size to permit liquid to pass therethrough at the rate required to operate the servo-motor 10—11 at the desired speed.

Then, when pump pressure suddenly rises due to the motor stalling, the control valve 32 will open wide enough to permit liquid to enter the port 44 faster than it can flow through the choke 47 with the result that the pressure in the port 44 and passage 46 will rise high enough to raise the piston 65 and thereby open the relief valve 63 as shown in dotted lines in Fig. 2. For clearness of illustration, the relief valve is shown wide open but, in practice, it ordinarily opens only a few thousandths of an inch. Opening the re-

relief valve 63 permits the pump to discharge into the reservoir 20.

During this time, the stroke control motor 10—11 is reducing pump displacement and thereby reducing the flow of liquid through the pipe 40 so that, just before pump displacement is reduced substantially to zero, the relief valve closes and then the control valve floats between a partly open and a partly closed position.

Since the control valve 32 opens at a predetermined maximum pump pressure and throttles the flow of liquid to the stroke control servo-motor 10—11 and to the relief valve servo-motor 65—66 both of which operate at very low pressures, it is not necessary that pump pressure exceed the predetermined maximum in order to cause the relief valve 63 to open for the reason that pressure continuing at the predetermined maximum will cause the control valve 32 to continue to open and thereby reduce its throttling action until the pressure in the lower end of the counterbore 66 is high enough to open the relief valve 63.

A pump to which the invention has been applied is thus enabled to deliver liquid at a given rate until pump pressure reaches a predetermined maximum and to then maintain that maximum at a substantially exact value irrespective of whether or not the motor driven by the pump should stall, or whether it should stall suddenly or gradually, or whether or not the discharge from the pump should be instantly blocked.

The arrangement shown is preferred and has proved highly successful. However, the servo-motor 10—11 could be operated by liquid supplied from a separate source, such as the gear pump 22, by simply having the control valve 32 control communication between that source and the port 44 instead of between the discharge pipe 15 and the port 44. The control valve would be exposed to pressure created by the pump 1, as in the present instance, and would operate in response to variations in pump pressure above and below the predetermined maximum, as explained above.

The invention herein set forth is susceptible of various modifications without departing from the scope thereof as hereafter claimed.

The invention is hereby claimed as follows:

1. The combination, with a pump having a fluid actuated stroke control motor for varying its displacement, of means for supplying motive fluid to said motor to operate the same, a control valve subjected at all times to pump pressure for controlling the flow of motive fluid to and from said motor and responsive to a predetermined maximum pump pressure to direct motive fluid to said motor, a servo-motor comprising a piston and a cylinder for overcoming the frictional resistance to movement of said valve, means for supplying motive fluid to said servo-motor at opposite ends of said piston, and means for maintaining a uniform preponderance of pressure at one end or the other of said piston.

2. The combination, with a pump having a fluid actuated stroke control motor for varying its displacement, of means for supplying motive fluid to said motor to operate the same, a control valve subjected at all times to pump pressure for controlling the flow of motive fluid to and from said motor and responsive to a predetermined maximum pump pressure to direct motive fluid to said motor, and means responsive to the flow of fluid to or from said motor for overcoming the frictional resistance to movement of said valve.

3. The combination, with a pump having a hydraulic stroke control motor for varying its displacement, of means for supplying liquid from said pump to said motor to operate the same, a control valve subjected at all times to pump pressure for controlling the flow of liquid to and from said motor and responsive to a predetermined maximum pump pressure to direct liquid to said motor, a hydraulic servo-motor for overcoming the frictional resistance to movement of said valve, and means for supplying motive liquid to said servo-motor.

4. The combination, with a pump having a hydraulic stroke control motor for varying its displacement, of means for supplying liquid from said pump to said motor to operate the same, a control valve subjected at all times to pump pressure for controlling the flow of liquid to and from said motor and responsive to a predetermined maximum pump pressure to direct liquid to said motor, and means responsive to the flow of liquid to or from said motor for overcoming the frictional resistance to movement of said valve.

5. The combination, with a pump having a fluid actuated stroke control motor for varying its displacement, of means for supplying motive fluid to said motor to operate the same, a control valve subjected at all times to pump pressure for controlling the flow of motive fluid to and from said motor and responsive to a predetermined maximum pump pressure to direct motive fluid to said motor, a fluid servo-motor connected to said valve for overcoming the frictional resistance thereof, and means responsive to the flow of fluid to and from said stroke control motor for causing operation of said servo-motor.

6. The combination, with a pump having a hydraulic stroke control motor for varying its displacement, of means for supplying liquid from said pump to said motor to operate the same, a control valve subjected at all times to pump pressure for controlling the flow of liquid to and from said motor and responsive to a predetermined maximum pump pressure to direct liquid to said motor, a hydraulic servo-motor connected to said valve for overcoming the frictional resistance thereof, and means responsive to the flow of liquid to and from said stroke control motor for causing operation of said servo-motor.

7. The combination, with a pump having a fluid actuated stroke control motor for varying its displacement, of means for supplying motive fluid to said motor to operate the same, a control valve subjected at all times to pump pressure for controlling the flow of motive fluid to and from said motor and responsive to a predetermined maximum pump pressure to direct motive fluid to said motor, a fluid servo-motor connected to said valve for overcoming the frictional resistance thereof, fluid channels connecting said servo-motor in circuit with said stroke control motor, and two oppositely arranged low pressure resistance valves connected in series with said stroke control motor to cause the pressure in one end of said servo-motor to be higher than the pressure in the other end thereof in response to operation of said stroke control motor in either direction.

8. The combination, with a pump having a hydraulic stroke control motor for varying its displacement, of means for supplying liquid from said pump to said motor to operate the same, a control valve subjected at all times to pump pressure for controlling the flow of liquid to and from

said motor and responsive to a predetermined maximum pump pressure to direct liquid to said motor, a hydraulic servo-motor connected to said valve for overcoming the frictional resistance thereof, fluid channels connecting said servo-motor in circuit with said stroke control motor, and two oppositely arranged low pressure resistance valves connected in series with said stroke control motor to cause the pressure in one end of said servo-motor to be higher than the pressure in the other end thereof in response to operation of said stroke control motor in either direction.

9. The combination, with a pump having a fluid actuated stroke control motor for varying its displacement, of means for supplying motive fluid to said motor to operate the same, a control valve subjected at all times to pump pressure for controlling the flow of motive fluid to and from said motor and responsive to a predetermined maximum pump pressure to direct motive fluid to said motor, and a relief valve connected at all times to said pump and operated by fluid under the control of said control valve.

10. The combination, with a pump having a fluid actuated stroke control motor for varying its displacement, of a relief valve connected to the discharge side of said pump and spring pressed to its closed position, a servo-motor for opening said valve and requiring a fluid pressure to open it which is higher than the fluid pressure required to operate said stroke control motor, means for supplying motive fluid to both of said motors to operate the same, and a control valve subjected at all times to pump pressure for controlling the flow of fluid to and from both of said motors and responsive to a predetermined maximum pump pressure to direct motive fluid to said motors.

11. The combination, with a pump having a hydraulic stroke control motor for varying its displacement, of a relief valve connected to the discharge side of said pump and spring pressed to its closed position, a servo-motor for opening said valve and requiring a fluid pressure to open it which is higher than the fluid pressure required to operate said stroke control motor, means for supplying liquid from said pump to both of said motors to operate the same, and a control valve subjected at all times to pump pressure for controlling the flow of liquid to and from both of said motors and responsive to a predetermined maximum pump pressure to direct liquid to said motors.

12. The combination, with a pump having a fluid actuated stroke control motor for varying its displacement, of means for supplying motive fluid to said motor to operate the same, a control valve subjected at all times to pump pressure for controlling the flow of motive fluid to and from said motor and responsive to a predetermined maximum pump pressure to direct motive fluid to said motor, means responsive to the flow of fluid to or from said motor for overcoming the frictional resistance to movement of said valve, and a relief valve connected to said pump and operated by fluid under the control of said control valve.

13. The combination, with a pump having a hydraulic stroke control motor for varying its displacement, of means for supplying liquid from said pump to said motor to operate the same, a control valve subjected at all times to pump pressure for controlling the flow of liquid to and from said motor and responsive to a predetermined

maximum pump pressure to direct liquid to said motor, means including a hydraulic servo-motor for overcoming the frictional resistance to movement of said valve, and a relief valve connected to said pump and operated by liquid supplied from said pump under the control of said control valve.

14. The combination, with a pump having a hydraulic stroke control motor for varying its displacement, of means for supplying liquid from said pump to said motor to operate the same, a control valve subjected at all times to pump pressure for controlling the flow of liquid to and from said motor and responsive to a predetermined maximum pump pressure to direct liquid to said motor, means responsive to the flow of liquid to or from said motor for overcoming the frictional resistance to movement of said valve, and a relief valve connected to said pump and operated by liquid supplied from said pump under the control of said control valve.

15. The combination, with a pump having a fluid actuated stroke control motor for varying its displacement, of means for supplying motive fluid to said motor to operate the same, a control valve subjected at all times to pump pressure for controlling the flow of motive fluid to and from said motor and responsive to a predetermined maximum pump pressure to direct motive fluid to said motor, means including a fluid operated servo-motor connected to said valve for overcoming the frictional resistance thereof, and a relief valve connected at all times to said pump and operated by fluid under the control of said control valve.

16. The combination, with a pump having a hydraulic stroke control motor for varying its displacement, of means for supplying liquid from said pump to said motor to operate the same, a control valve subjected at all times to pump pressure for controlling the flow of liquid to and from said motor and responsive to a predetermined maximum pump pressure to direct liquid to said motor, a hydraulic servo-motor connected to said valve for overcoming the frictional resistance thereof, means responsive to the flow of liquid to and from said stroke control motor for causing operation of said servo-motor, and a relief valve connected to said pump and operated by liquid supplied from said pump under the control of said control valve.

17. The combination, with a pump having a fluid actuated stroke control motor for varying its displacement, of means for supplying motive fluid to said motor to operate the same, a control valve subjected at all times to pump pressure for controlling the flow of motive fluid to and from said motor and responsive to a predetermined maximum pump pressure to direct motive fluid to said motor, a fluid servo-motor connected to said valve for overcoming the frictional resistance thereof, fluid channels connecting said servo-motor in circuit with said stroke control motor, two oppositely arranged low pressure resistance valves connected in series with said stroke control motor to cause the pressure in one end of said servo-motor to be higher than the pressure in the other end thereof in response to operation of said stroke control motor in either direction, and a relief valve connected to said pump and operated by fluid under the control of said control valve.

18. The combination, with a pump having a hydraulic stroke control motor for varying its displacement, of means for supplying liquid from

said pump to said motor to operate the same, a control valve subjected at all times to pump pressure for controlling the flow of liquid to and from said motor and responsive to a predetermined maximum pump pressure to direct liquid to said motor, a hydraulic servo-motor connected to said valve for overcoming the frictional resistance thereof, fluid channels connecting said servo-motor in circuit with said stroke control motor, two oppositely arranged low pressure resistance valves connected in series with said stroke control motor to cause the pressure in one end of said servo-motor to be higher than the pressure in the other end thereof in response to operation of said stroke control motor in either direction, and a relief valve connected to said pump and operated by liquid supplied from said pump under the control of said control valve.

19. The combination, with a pump having a fluid actuated stroke control motor for varying its displacement, of means for supplying motive fluid to said motor to operate the same, a control valve subjected at all times to pump pressure for controlling the flow of motive fluid to and from said motor and responsive to a predetermined maximum pump pressure to direct motive fluid to said motor, and means including a

fluid servo-motor for exerting upon said valve in one direction or the other a force which remains substantially constant during operation of said pump and which acts upon said valve in a direction opposite to its direction of movement to thereby resist overrun of said valve and to assist in starting said valve in said opposite direction.

20. The combination, with a pump having a hydraulic stroke control motor for varying its displacement, of means for supplying liquid from said pump to said motor to operate the same, a control valve subjected at all times to pump pressure for controlling the flow of liquid to and from said motor and responsive to a predetermined maximum pump pressure to direct liquid to said motor, and means including a servo-motor operated by liquid supplied by said pump for exerting upon said valve in one direction or the other a force which remains substantially constant during operation of said pump and which acts upon said valve in a direction opposite to its direction of movement to thereby resist overrun of said valve and to assist in starting said valve in said opposite direction.

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