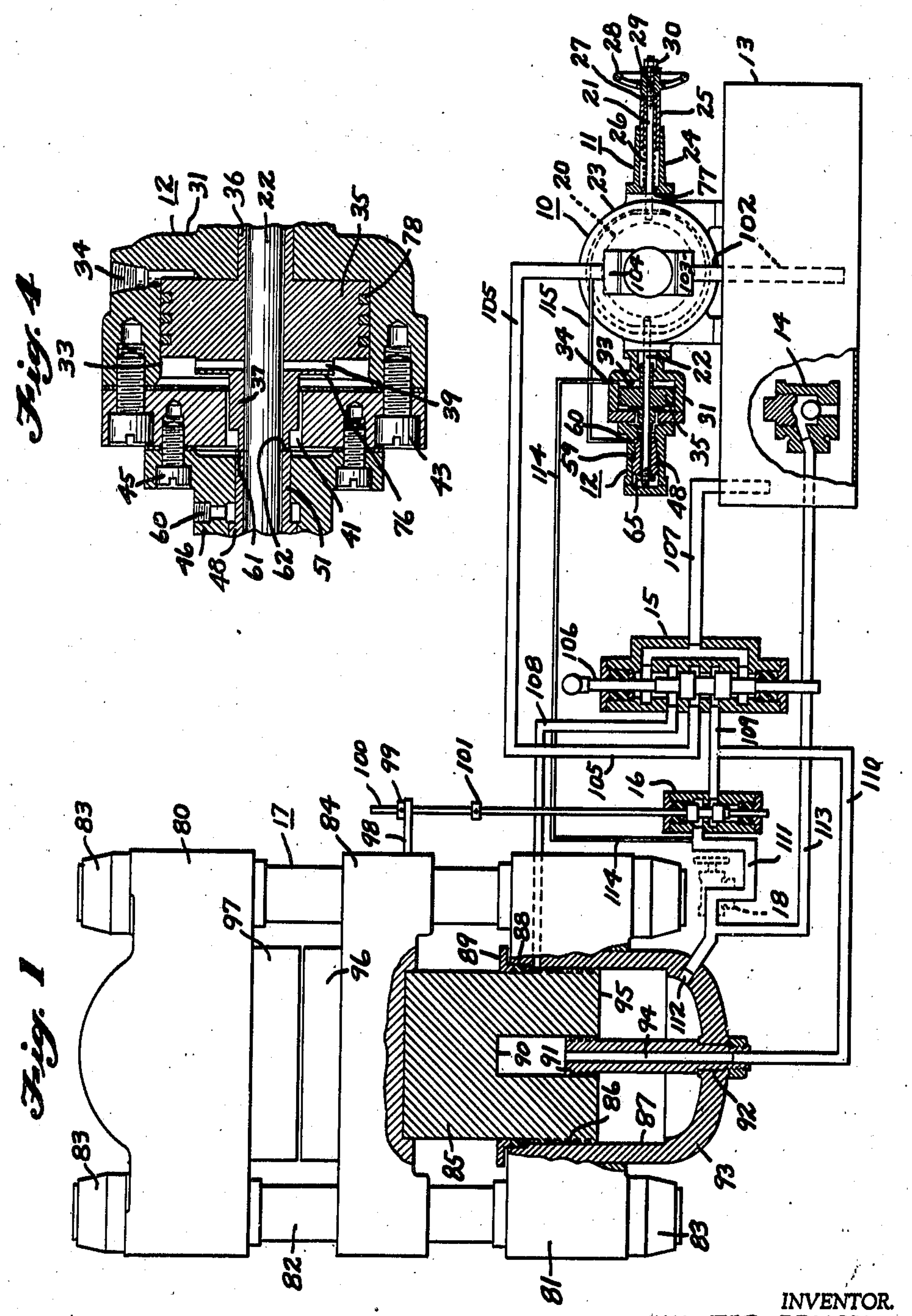
Oct. 14, 1941. W. ERNST 2,258,981

SELECTIVE DELIVERY REDUCTION MEANS FOR VARIABLE DELIVERY PUMPS

Filed Sept. 16, 1938 3 Sheets-Sheet 1



INVENTOR.
WALTER ERNST
BY Toulmin & Toulmin
ATTORNEYS

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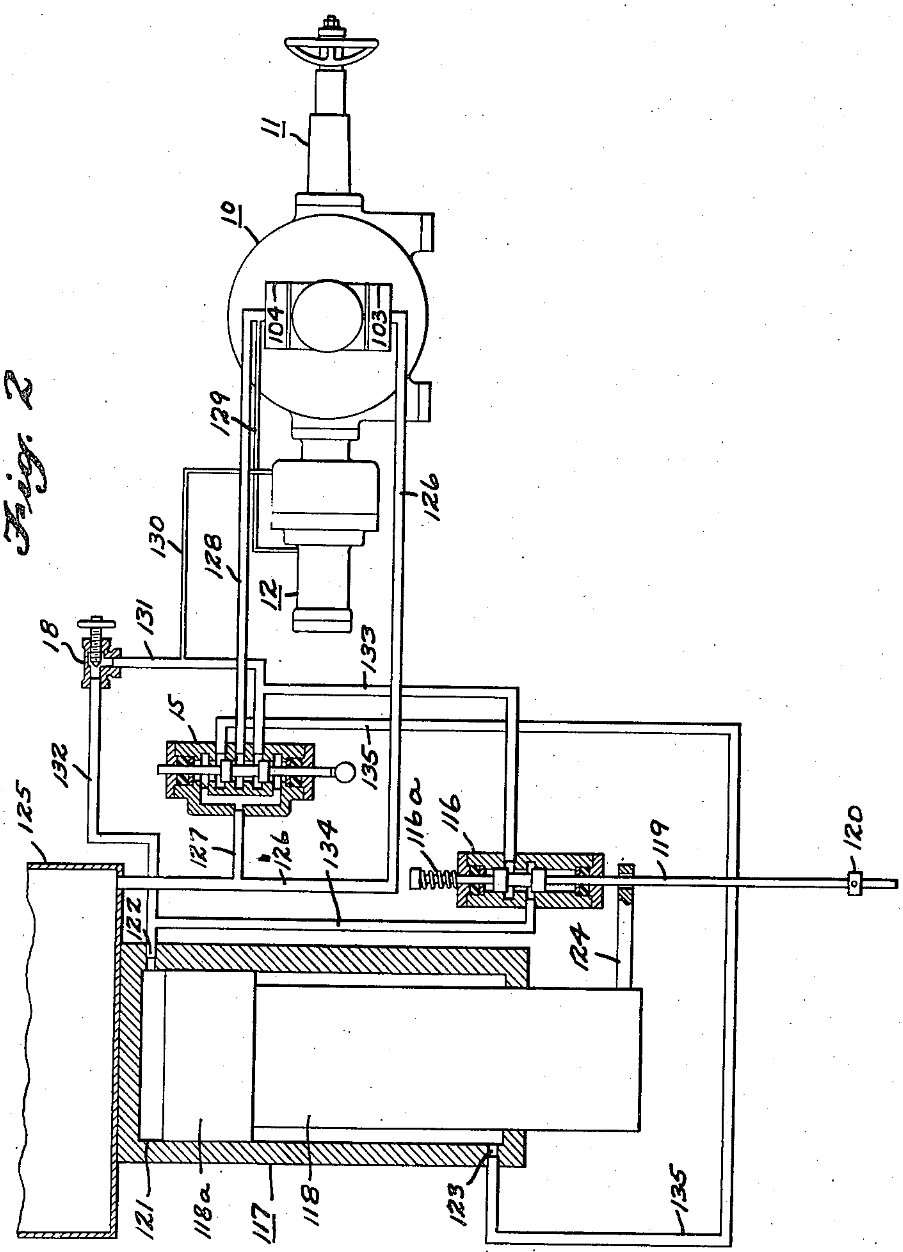
Fig. 2



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WALTER ERNST

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ATTORNEYS

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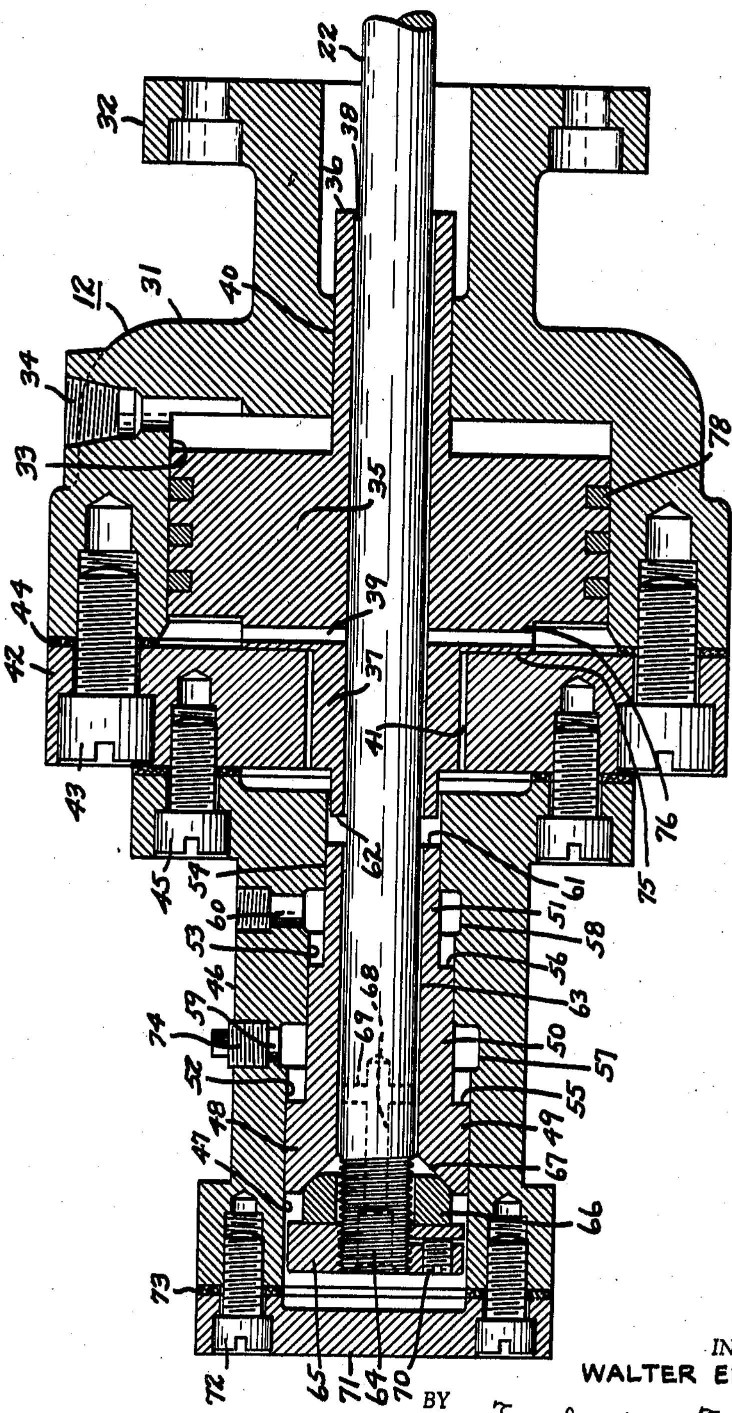
Fig. 3



INVENTOR.
WALTER ERNST

BY Toulmin & Toulmin
ATTORNEYS

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2,258,981

SELECTIVE DELIVERY REDUCTION MEANS FOR VARIABLE DELIVERY PUMPS

Walter Ernst, Mount Gilead, Ohio, assignor to The Hydraulic Press Corp. Inc., Wilmington, Del., a corporation of Delaware

Application September 16, 1938, Serial No. 230,260

8 Claims. (Cl. 60—52)

This invention relates to hydraulic machine circuits, and in particular, to means for regulating the speed of a hydraulic motor, such as a press ram, by altering the delivery of a variable delivery pump supplying pressure fluid to the circuit.

One object of the invention is to provide means for selectively reducing the delivery of a variable delivery pump circuit supplying pressure fluid to a hydraulic motor in response to the motion of said motor, or a portion thereof, to a predetermined position.

Another object is to provide a delivery-regulating device for a variable delivery pump circuit which will cause a reduction of pump output and hence a slowing down of the hydraulic motor connected thereto when the movable motor member, such as the ram, reaches a predetermined position, preferably before engaging the workpiece or the opposing member.

Another object is to provide a hydraulic press-operating circuit having a hydraulic motor and a variable delivery pump of such a character that the delivery of the variable delivery pump is reduced when the plunger of the hydraulic motor reaches a predetermined position, and particularly before the movable member of the press engages the stationary member or workpiece, and also before the motor has encountered substantial resistance to its operation.

Another object is to provide a variable delivery pump and a control unit therefor which is adapted to shift the flow-control element of the pump independently of the shifting accomplished by an additional piston responsive to the attainment of a predetermined pressure in the circuit served by the pump.

Another object is to provide such a control unit for a variable delivery pump, wherein packings are reduced to a minimum and are substantially eliminated, thereby eliminating to a great extent the friction arising from the presence of such packings and correspondingly increasing the sensitivity of the control unit.

In the drawings:

Figure 1 is a side elevation, partly in section, of a hydraulic press-operating circuit including means for selectively reducing the delivery of a variable delivery pump when the press platen reaches a predetermined position, the press having an upwardly acting ram including a booster ram.

Figure 2 is a modification of the circuit shown in Figure 1, with a downwardly acting press ram and without a booster ram.

Figure 3 is an enlarged longitudinal section through the control mechanism of the variable delivery pump for providing selective fluid delivery reduction according to the present invention, with the moving pistons disengaged to render the unit temporarily inoperative.

Figure 4 is a view similar to Figure 3, but with the pistons engaging one another and shifted to their extreme right-hand positions by the spring unit of the variable delivery pump.

General construction

In general, the invention consists of a device for altering the delivery of a variable delivery pump by shifting the control rod thereof when the press plunger of a press reaches a predetermined position. When the press plunger reaches that position it shifts a valve, whereupon pressure fluid is admitted to a piston mounted on the control rod of the variable delivery pump, and this piston shifts the control rod and the shifting of the pump to reduce the delivery of the pump. This action occurs before the press plunger engages the workpiece or before a substantial resistance has been built up to oppose the motion of the press plunger.

In many applications of hydraulic motors, and particularly hydraulic presses, it has been found desirable to move the press plunger or platen rapidly toward the work, and then to cause it to move more slowly. In plastic molding machines, for example, where a synthetic plastic material, such as a synthetic resin, is placed in the mold in the form of a powder or briquette which must be softened by heat before it will flow readily into the more intricate portions of the mold cavity, it is essential that the mold halves be moved very slowly during the final portion of the closing stroke. It is also advisable that the transition from rapid to slow motion shall take place before any substantial resistance has been encountered in closing the molds. Other applications of hydraulic motors also occur, where it is desirable to provide an initial high speed and a final slow speed, with the shifting point brought about at a predetermined position rather than by the attainment of a predetermined resistance to the progress of the plunger of a movable motor member.

Hitherto, it has been attempted to control the output of a variable delivery pump to effect a reduction in its output after the work has been engaged, or when a predetermined resistance has been built up. The present invention, however, and the arrangement of the control circuit enable a selective reduction of the pump output, and hence, a slowing down of the driven mechanism, such as the hydraulic motor, before the work is engaged or a substantial resistance has been built up.

In general, a typical circuit for accomplishing the objects of this invention is shown in Figure 1, and consists of a variable delivery pump 10 having a spring-urged device 11 for urging the flow-control element of the pump in one direction, and a pump control unit 12 for urging it in the opposite direction. A tank 13 supplies fluid for the operation of the circuit, and contains a check valve 14 for purposes hereinafter explained. A four-way main control valve 15 and a two-way auxiliary valve 16 are provided for the regulation of the supply of fluid to the motor of the hydraulic press 17. A choke or fluid flow-restricting element 18 is optionally inserted in the circuit of Figure 1, and is regularly inserted in the circuit of Figure 2. The auxiliary two-way valve 16 is operated by the motion of the platen of the press 17 at a predetermined position, as hereinafter explained.

Variable delivery pump control arrangement

The variable delivery pump 10 is of the radial piston type well known to those skilled in the art, but any other type of variable delivery pump may be employed, the radial piston type being merely shown for purposes of example. The variable delivery pump 10 is provided with a flow-control element or shiftring 20, which is mounted upon the control rods 21 and 22 slidably supported in the pump casing 23 and passing outwardly therethrough. The shiftring 20 ordinarily encircles the secondary rotor of the pump and by varying the eccentricity of the latter relatively to the axis of rotation of the primary rotor or cylinder barrel alters the delivery or output of the pump. When the axis of the secondary rotor coincides with that of the primary rotor or cylinder barrel, and the eccentricity is zero, the shiftring 20 is then said to be in its neutral or zero delivery position. Under these circumstances, as is well known to those skilled in the hydraulic art, the pistons of the pump 10 will not reciprocate and hence the pump delivers substantially no fluid.

The control rod 21 is urged to the right to shift the shiftring or flow-control element 20 into a full delivery position by the spring-urged device 11, consisting of a stationary tubular casing 24 within which is telescopically mounted a movable tubular casing 25. The stationary casing 24 is secured to the pump casing 23 and both casings 24 and 25 inclose a coil spring 26, one end of which rests against the inner left end wall of the stationary casing 24, whereas the other end engages the right-hand end wall of the movable casing 25, which has a ball thrust bearing 27 associated therewith and engaged on its opposite side by the hub of a hand wheel 28 internally threaded upon the threaded portion 29 of the control rod 21. A locknut 30 beyond the hand wheel 28 enables the locking of the hand wheel 28 in any desired position of adjustment. The control unit 12, in general, urges the control rod 22 and pump shiftring 20 to the left when it receives pressure fluid, thereby tending to overcome the thrust of the coil spring 26 and move the shiftring 20 back toward its zero delivery or neutral position.

The control unit 12 (Figure 3) consists of a housing 31 attachable by its flanged portion 32 to the pump casing 23. This housing 31 contains a cylinder bore 33 having a threaded entrance port 34, giving access to the end thereof nearest the pump casing 23. Reciprocable within the cylinder bore 33 is an auxiliary piston 35 having sleeve-like extensions or hubs 36 and 37 extending in opposite directions along the control rod 22 but separated therefrom by a substantial clearance space 38 therebetween. Fluid leaking past the auxiliary piston 35 to the left-hand end of the cylinder bore 33 escapes by way of the transverse passageway 39 into the clearance space 38, and thence along the control rod 22, back into the pump casing 23, the clearance space 38 forming the annular passageway along the control rod 22. An accurate sliding fit is maintained in the bore 40 between the hub 36 and the casing 31 so that no packing is required at this location. The hub 37, however, is separated by a clearance space 41 from the cylinder head 42, which is bolted to the housing 31 by means of the screws 43 and with the gasket 44 therebetween to prevent leakage.

Bolted to the cylinder head 42, as by the screws 45, is a housing 46 containing a cylinder bore, generally designated 47, and receiving a stepped piston, generally designated 48. The stepped piston 48 consists of three portions 49, 50 and 51, of different diameters, respectively reciprocable in the bore portions 52, 53 and 54 of the cylinder bore 47. This construction provides annular piston areas 55 and 56 opening into bore enlargements 57 and 58, served by the threaded ports 59 and 60; and also provides an annular end wall 61 which is adapted to be engaged by the annular end wall 62 of the piston hub 37 when the piston 48 is moved to the right to close up the space (Figure 3) between the annular end walls 61 and 62, in the manner shown in Figure 4. For this purpose the stepped piston 48 is separated from the control rod 22 by a clearance space 63, similar to the clearance space 38 between the auxiliary piston 35 and the control rod 22.

The outer end of the control rod 22 is threaded, as at 64 (Figure 3), and provided with a locknut 65 engaging a collar 66, which, in turn, engages the conical bore 67 in the end of the stepped piston 48. A longitudinal passageway 68, communicating with a transverse passageway 69 in the control rod 22, provides for the drainage of fluid which escapes past the stepped piston 48. Such fluid passes through the passageways 68 and 69, and through the clearance spaces 63 and 38, along the control rod 22 to the pump casing 23.

In Figure 3 the stepped piston 48 is shown as separated by a quarter of an inch from the auxiliary piston 35, yet the latter is at the extreme end of its stroke in the left-hand direction. This separation between the end walls 61 and 62 of the piston portions 51 and 37, respectively, is provided to render the unit 12 temporarily inoperative at the will of the operator. When it is desired to render the unit operative (Figures 1 and 4), the operator rotates the locknut 65, thereby moving the stepped piston 48 to the right, along the control rod 22, until the end wall 61 engages the end wall 62. Thus, when pressure is admitted through the port 34 to the cylinder bore 33 so as to urge the auxiliary piston 35 to the left, the latter likewise engages the end wall 61 of the stepped piston 48, moving it to the left and with it the control rod 22 by reason of the connection provided by the collar 66 and locknut 65. The locknut 65 may be locked at any desired position along the threaded portion 64 by turning the set screw 70. The left-hand end of the cylinder bore 47 is closed by the end plate 71, secured to the housing 46 by the screws 72, leakage being prevented by the gasket 73.

The stepped piston 48 is provided for the purpose of creating a multiplicity of piston areas of different sizes so that the pump flow-control element or shiftring 20 may be shifted to its neutral position at one of a plurality of selected pressures. The particular pressure selected is determined by whether the control conduit is connected to the port 60 or to the port 59. In the example shown in Figure 3, the port 59 is illustrated as closed by the threaded plug 74 so that the port 60, cylinder bore 53 and annular piston area 56 are in use. The same arrangement is shown in Figure 1. It will also be obvious that a third piston area will be available if both of the ports 59 and 60 are connected to the pressure circuit, thereby subjecting the combined piston areas 56 and 55 to the action of the pressure fluid. The stepped piston construction shown at the left-hand end of Figure 3 in itself is described and claimed in the copending application of Ernst, et al., Ser. No. 225,155, filed August 16, 1938, now Patent No. 2,229,965.

It will be observed that the motion of the auxiliary piston 35 to the left is limited by the shoulder 75 at the end of the portion 76 containing the transverse passageway 39. In Figure 3 the auxiliary piston 35 is shown in its extreme left-hand position, which position it will occupy only when there is sufficient pressure in the cylinder bore 33 to overcome the force of the coil spring 26. By turning the locknut 65 the amount of movement of the control rod 22, which may be brought about by the auxiliary piston 35, is increased or decreased, depending upon the direction in which the nut 65 is turned.

It will be observed that there is no packing engaging the moving parts excepting the oil seal 77 (Figure 1) surrounding the control rod 21 at the point where it passes out of the spring casing 11 into the pump casing 23. As the oil seal 77 is not under pressure, however, it causes no appreciable friction by its engagement with the control rod 21. The piston rings 78 in the auxiliary piston 35 assist in preventing leakage thereby, but where such leakage occurs it is rapidly taken care of by the leakage system previously described and consisting of the passages 39, 68 and 69 and the clearance spaces 63 and 38 surrounding the control rod 22. The thrust of the spring 26 and therefore the force opposing the action of the pistons 35 and 48 is regulated by turning the hand wheel 28.

Hydraulic press circuit with upwardly moving platen and booster ram

The variable delivery pump with the control unit described above is capable of a variety of uses, Figure 1 showing the press having an upwardly moving platen and a booster ram. In Figure 1 the press 17 is provided with a head 80, a bed 81 interconnected by the strain rods 82 having the nuts 83 threaded upon the ends thereof. The press 17 is provided with an upwardly moving platen 84, to which is attached the main plunger 85 having a piston head 86 reciprocable in the main cylinder bore 87, the entrance to which is closed by the packing 88 and gland 89. The main plunger 85 is hollow and contains a booster cylinder 90, the walls of which are engaged by the end of the booster ram 91, which consists of a hollow tube mounted in the aperture 92 at the lower end of the main cylinder 93, and having a bore 94 extending longitudinally therethrough. The booster cylinder 90 is provided to move the platen 84 more rapidly toward its closing position than would be possible by using the piston area 95 of the main plunger 85 alone.

The platen 84 may operate in any manner upon the workpiece or upon the other mechanism to be operated. In Figure 1 the platen 84, for purposes of example, is shown as carrying a die half 96 cooperating with the stationary die half 97 mounted upon the press head 80. The platen 84 is also provided with a platen arm 98 adapted to engage a collar 99 upon the valve rod 100 of the two-way auxiliary valve 16, previously described. An additional collar 101 is provided beneath the platen arm 98 so that the latter will shift the valve rod 100, and change the setting of the two-way valve 16 at the opposite ends of its stroke.

The variable delivery pump is connected to the tank 13 by the suction conduit 102 from the suction connection 103. The fluid received along the suction conduit 102 is pumped through the pressure head 104, along the conduit 105 to the four-way main control valve 15 having the valve rod 106. From the valve 15 the discharge conduit 107 leads back to the tank 13, and the conduits 108 and 109 lead respectively to the upper end of the main cylinder bore 87 and to the two-way auxiliary valve 16. A branch conduit 110 leads from the conduit 109 to the bore 94 within the stationary booster ram 91. A conduit 111 leads from the two-way valve 16 to the port 112 in the lower end of the main cylinder bore 87, and in this conduit a choke 18 is optionally inserted. A branch conduit 113 runs from the conduit 111 to the check valve 14 within the tank 13. A control conduit 114 also runs from the conduit 111 to the port 34 of the cylinder bore 33, whereas the control conduit 115 runs from the pressure conduit 105 to either or both of the ports 59 and 60, adapted to admit pressure fluid to the stepped piston 48.

In the operation of the circuit shown in Figure 1, the variable delivery pump 10 is started in operation, it being assumed that the main plunger 85 is in its lower position opposite to that shown in Figure 1. It is also assumed that the two-way auxiliary valve 16 is in the opposite position from that shown in Figure 1, namely, with its valve heads in their lowered positions. Fluid is then pumped by the variable delivery pump from the tank 13, through the suction conduit 102, along the pressure conduit 105, through the four-way main control valve 15, thence through the conduits 109 and 110 and the bore 94 of the booster plunger 91, into the booster cylinder 90, the auxiliary valve 16 being in its lowered or closed position. Pressure fluid within the booster cylinder 90 acts against the limited area thereof and causes the main plunger 85 and platen 84 to be moved upwardly at a rapid rate. The void thus produced in the main cylinder bore 87 is filled with fluid through the port 112, the conduits 111 and 113 and the check valve 14 from the tank 13.

When the lower mold half 96 has almost reached the upper mold half 97, or at any desired point in the operation of the press 17, the platen arm 98 engages the collar 99 and lifts the valve rod 100 of the auxiliary valve 16, opening the latter by shifting its heads to the positions shown in Figure 1. Since the pressure fluid can now pass from the conduit 109 through the auxiliary valve 16, and the conduit 111 and port 112, into the main cylinder bore 87, it encounters less resistance therein than in the booster cylinder 90. Most of the discharge from the variable delivery pump 10, on this account, will now be diverted to the main cylinder bore 18, where it acts against the large piston area 95 thereof, with the result that a sufficient pressure will be produced to continue the lifting of the main plunger 85 but at a reduced speed and with a much greater potential pressing force. Pressure fluid now backs up in the conduit 114 and passes through the port 34 (Figure 3), into the cylinder bore 33, where it acts against the piston head 35 and moves it to the left.

Assuming that the stepped piston 48 has been brought into operative engagement by rotating the nut 65 in a clockwise direction (Figure 4) and the gap between the end walls 61 and 62 is closed up from the position shown in Figure 3 to that shown in Figure 4, the motion of the piston 35 will be transmitted to the control rod 22, shifting the latter to the left by overcoming the thrust of the coil spring 26. This movement shifts the flow-control element or shiftring 20 of the pump 10 toward its neutral or zero delivery position, thereby reducing the delivery of the pump 10 and placing the latter upon part stroke. The amount of reduction in pressure depends upon the adjustment of the nut 65. This reduction in the discharge of the pump 10 thus slows up the movement of the main plunger 85, the speed of which can be adjusted by adjusting the nut 65. The area of the piston head 35 is preferably made sufficiently large so that the pressure, due to the weight of the moving parts 84 and 85, will be sufficient to cause the shifting of the piston head 35 to the left as soon as the two-way valve 16 is opened by the engagement of the platen arm 98 with the collar 99 on the control rod 100.

However, the weight of these moving parts may not be sufficiently large to provide enough pressure to shift the piston head 35, as may occur in the case of a downwardly acting press plunger with a booster cylinder in which no pressure would build up because the ram travels downwardly under the influence of gravity. In that event the choke 18 may be inserted in the conduit 111, as shown by the dotted lines in Figure 1. This choke 18 artificially increases the pressure in the conduit 114 and therefore causes the piston head 35 to move.

The piston head 35 is intended to reduce the stroke of the pump but not to reduce it to zero. Thus, after the two-way valve 16 is opened at a predetermined point in the motion of the platen 84, the pump 10 is on part stroke and is still delivering pressure fluid. When the main plunger 85 meets a sufficient positive resistance so that the pressure fluid backing up in the conduit 115 is of sufficient force to shift the stepped piston 48 to the left and overcome the thrust of the coil spring 26, the control rod 22 and shiftring 20 of the pump are shifted to substantially neutral position. The pump in this position is arranged to deliver just enough fluid to take care of leakage in the circuit, if such leakage is present. To reverse the motion of the platen 84 the valve rod 106 of the main control valve 15 is shifted to its opposite position, whereby pressure fluid is delivered to the conduit 108, into the space at the upper end of the main cylinder bore 87.

Since the two-way valve 16 remains open until the platen arm 98 encounters the lower collar 101 on the valve rod 100, fluid escapes from the lower end of the main cylinder bore 87, through the port 112, the conduit 111, the two-way valve 16, the conduit 109, the main control valve 15 and the conduit 107, into the tank 13. At the same time fluid escapes from the booster cylinder 90, through the bore 94, the conduit 110, the conduit 109, the main control valve 15 and the conduit 107, into the tank 13. The platen 84, therefore, descends until the platen arm 98 engages the collar 101 and closes the two-way valve 16. Pressure then builds up in the circuit and backs up in the conduit 115 to shift the stepped piston 48, the control rod 22 and shiftring 20 to the left to reduce the discharge of the pump 10 substantially to zero.

Hydraulic press circuit having downwardly moving plunger without booster ram

The modified circuit in Figure 2 employs the same variablie delivery pump 10, with its spring unit 11 and control unit 12 as previously described. The four-way valve 15 is likewise the same as in Figure 1. The two-way valve 116, however, differs from the two-way valve 16 of Figure 1 by having a coil spring 116ª urging the valve rod 119 upwardly into its open position, so that the valve 116 is a normally open valve. The valve rod 119 is provided with a collar 120, arranged in close proximity to the press 117. The latter differs from the press 17 of Figure 1 by having a downwardly acting plunger 118 without a booster plunger, as in Figure 1. The plunger 118 is provided with a piston head 118ª reciprocable in the main cylinder bore 121. The ports 122 and 123 lead, respectively, into the upper and lower ends of the main cylinder bore 121. The main plunger 118 is provided with an arm 124 adapted to engage the collar 120 and close the auxiliary valve 116 when the main plunger 118 has descended to a predetermined position, as regulated by the position of the collar 120 on the valve rod 119.

The tank 125 is connected to the pump 10 by the conduit 126, from which the conduit 127 runs to the discharge side of the main control valve 15, the pressure side of which is connected by the conduit 128 to the pressure connection 104 of the pump 10. The conduit 129, running from the pressure conduit 128 to the control unit 12, corresponds to the conduit 115 in the circuit of Figure 1, and the conduit 130 similarly corresponds to the conduit 114 of Figure 1. From the main control valve 15 the conduit 131 runs to the choke 18, from which the conduit 132 runs to the upper port 122 of the main cylinder bore 120. From the conduit 131 a branch conduit 133 runs to the two-way auxiliary valve 116, from the opposite side of which the conduit 134 runs to a junction with the conduit 132. The conduits 133 and 134 and the valve 116 thus provide a by-pass line around the choke 18 when the valve 116 is open. From the main control valve 15 the conduit 135 runs to the lower port 123 in the main cylinder bore 120 beneath the piston head 118ª.

In the operation of the circuit of Figure 2 there is no booster circuit as in Figure 1. The two-way valve, however, makes it possible to introduce resistance in the circuit and artificially increase the pressure acting upon the control unit 12 by means of the choke 18. In the initial portion of the downward stroke of the main plunger 118 the two-way valve 116 is held open by its coil spring 116ª. Fluid from the supply tank 125 enters the pump through the conduit 126, and is discharged through the conduit 128, the main control valve 15, the conduits 131 and 133, the normally open auxiliary valve 116, the conduits

134 and 132 and the port 122, into the upper end of the main cylinder bore 121. It will be understood that a surge valve may be provided between the supply tank and the cylinder bore 121 to assist in the prefilling of the latter during the descent of the main plunger 118, but this surge valve has been omitted for the sake of simplifying the showing.

The main plunger 118 descends until the arm 124 engages the collar 120 and shifts the valve rod 119 so as to overcome the urge of the coil spring 116a and close the two-way auxiliary valve 116. The by-pass line around the choke 18 is now closed so that henceforth pressure fluid must flow from the main control valve 15, through the conduit 131, the choke 18 and the conduit 132, into the port 122 at the upper end of the main cylinder bore 121. The resistance built up by the choke 18 causes pressure fluid to back up in the conduit 130 and enter the port 34 and cylinder bore 33 in the control unit 12 (Figure 3). This shifts the auxiliary piston 35 to the left to reduce the pump stroke, in the manner described in connection with Figure 1, so that during the remainder of the stroke of the main plunger 118 the pump 10 operates upon a reduced stroke, the speed of the main plunger 118 being correspondingly reduced. If a surge valve has been used to prefill the main cylinder bore 121 during the initial part of the stroke, means must be provided to close this surge valve so as to permit the slowing down of the main plunger 118. The surge valve may be closed, for example, by an additional platen arm, similar to the platen arm 124 and similarly engaging a collar on a control rod adapted to close the surge valve at a predetermined position upon the down stroke of the main plunger 118.

While the circuit shown in Figure 2 has been illustrated as operating in connection with a downwardly acting press, it will be evident that the arrangement may be used with any hydraulic motor regardless of whether the plunger 118 is downwardly acting, upwardly acting or horizontal. To reverse the motion of the main plunger 118 and retract it, the main control valve 15 is shifted to its opposite position so that pressure fluid is discharged through the conduit 135 and port 123 beneath the piston head 118a, thereby raising the main plunger 118. The arm 124 thereupon releases the collar 120 so that the valve rod 119 moves upwardly, under the urge of the coil spring 116a, and shifts the auxiliary valve 116 to its normally open position. Fluid can then escape through the port 122, the conduit 134, the valve 116, the conduits 133 and 131, the main control valve 15 and the conduits 127 and 126, back into the supply tank 125.

It will be understood that I desire to comprehend within my invention such modifications as come within the scope of the claims and the invention.

Having thus fully described my invention, what I claim as new and desire to secure by Letters Patent, is:

1. In a hydraulic circuit, a main cylinder, a main plunger therein, a variable delivery pump hydraulically connected to said main cylinder and having a movable flow control element, yielding means for urging said flow control element in a flow-increasing direction, an auxiliary cylinder, an auxiliary piston therein connected to move said flow control element in a flow-reducing direction, a control cylinder constantly connected to the pump discharge, a control piston in said cylinder, said control piston being movable independently of said auxiliary piston and being responsive to a predetermined pressure in said control cylinder for moving said flow control element to its zero delivery position, means responsive to the travel of said main plunger to a predetermined position during its advancing stroke for admitting pressure fluid to said auxiliary cylinder, whereby to reduce the flow from said pump to said main cylinder and to reduce the speed of said main plunger, and means responsive to a predetermined point of travel of said main plunger during its retraction stroke for causing said main plunger to convey fluid pressure to said auxiliary piston for actuating the same so as to move said flow control element to a restricted delivery position.

2. In a hydraulic circuit, a main cylinder, a main plunger therein, a variable delivery pump hydraulically connected to said main cylinder and having a movable flow control element, yielding means for urging said flow control element in a flow-increasing direction, an auxiliary cylinder, an auxiliary piston therein connected to move said flow control element in a flow-reducing direction, a control cylinder constantly connected to the pump discharge, a control piston in said cylinder, said control piston being movable independently of said auxiliary piston and being responsive to a predetermined pressure in said control cylinder for moving said flow control element to its zero delivery position, a fluid flow-restricting device hydraulically connected with said auxiliary cylinder and adapted to convey pressure fluid from said pump to said main plunger, conduit means adapted to convey pressure fluid from said pump to said main plunger without passing said pressure fluid through said flow-resricting device, and means responsive to the travel of said main plunger to a predetermined position for building up pressure between said pump and said flow-restricting means and admitting said pressure to said auxiliary cylinder, thereby moving said flow control element in said flow reducing direction.

3. In a hydraulic circuit, a main cylinder, a main plunger therein, a variable delivery pump hydraulically connected to said main cylinder and having a movable flow control element, yielding means for urging said flow control element in a flow-increasing direction, an auxiliary cylinder, an auxiliary piston therein connected to move said flow control element in a flow-reducing direction, a control cylinder constantly connected to the pump discharge, a control piston in said cylinder, said control piston being movable independently of said auxiliary piston and being responsive to a predetermined pressure in said control cylinder for moving said control element to its zero delivery position, a fluid flow-restricting device hydraulically connected with said auxiliary cylinder and adapted to convey pressure fluid from said pump to said main plunger, conduit means for conveying fluid from said pump to said main plunger without passing through said flow-restricting device, means adapted in response to the travel of said main plunger to a predetermined position to pass pressure fluid from said pump to said main plunger through said flow-restricting device, and means adapted in response to a second predetermined pressure, less than said first mentioned pressure, and prevailing between said flow-restricting device and said pump to actuate said auxiliary piston for caus-

ing the latter to move said flow control element into a restricted delivery position.

4. In a hydraulic circuit, a main cylinder, a main plunger therein, a variable delivery pump hydraulically connected to said main cylinder and having a movable flow control element, yielding means for urging said flow control element in a flow-increasing direction, an auxiliary cylinder, an auxiliary piston therein connected to move said flow control element in a flow-reducing direction, a control cylinder constantly connected to the pump discharge, a control piston responsive to a predetermined pressure in said control cylinder for moving said flow control element to its zero delivery position, an auxiliary valve, and means responsive to the travel of said main plunger to two predetermined positions respectively during the advancing and retraction stroke of said plunger for shifting said valve and admitting pressure fluid to said auxiliary cylinder, whereby to shift said flow control element and reduce the flow from said pump.

5. In a hydraulic circuit, a main cylinder, a main plunger therein having a main area and a booster area associated therewith, a variable delivery pump having a movable flow-control element, yielding means for urging said flow-control element in a flow-increasing direction, an auxiliary cylinder, an auxiliary piston therein, means for transmitting the thrust of said auxiliary piston to said flow-control element in the flow-reducing direction, an auxiliary valve arranged in one position to admit pressure fluid from said pump to said booster area and in another position to admit pressure fluid to said main area and to said auxiliary cylinder, and means responsive to the travel of said main plunger to a predetermined position for shifting said valve to admit pressure fluid to said main area and to said auxiliary cylinder, whereby to shift said flow-control element and reduce the flow from said pump.

6. In a hydraulic circuit, a main cylinder, a main plunger therein having a main area and a booster area associated therewith, a variable delivery pump having a movable flow-control element, yielding means for urging said flow-control element in a flow-increasing direction, an auxiliary cylinder, an auxiliary piston therein, means for transmitting the thrust of said auxiliary piston to said flow-control element in the flow-reducing direction, an auxiliary valve arranged in one position to admit pressure fluid from said pump to said booster area and in another position to admit pressure fluid to said main area and to said auxiliary cylinder, a fluid flow-restricting device insertable in said circuit between said main cylinder and said pump, and means responsive to the travel of said main plunger to a predetermined position for operating said valve to admit pressure fluid to said auxiliary cylinder and for directing the flow from said pump to said main cylinder through said flow-restricting device.

7. In a hydraulic circuit, a main cylinder, a main plunger having a main advancing area and a retraction area, booster cylinder and plunger means associated therewith, a variable delivery pump having a movable flow-control member, yielding means for urging said flow-control element in a flow-increasing direction, an auxiliary cylinder, an auxiliary piston therein connected to said flow-control member to move it in the flow-reducing direction, a valve arranged in a first position to admit pressure fluid from said pump to said booster cylinder and in a second position to admit pressure fluid to said main advancing area and to said auxiliary cylinder, means responsive to the travel of said main plunger to a predetermined position during its forward stroke to shift said valve from said first position to said second position to admit pressure fluid to said auxiliary cylinder to reduce the flow of said pump, and means responsive to the travel of said main plunger to a predetermined position during its retraction stroke to shift said valve from said second position to said first position to cause fluid entrapped between said auxiliary cylinder and said advancing area to actuate said auxiliary piston so as to move said flow-control member in said flow-reducing direction.

8. In a hydraulic circuit, a main cylinder, a main piston having an advancing area and a retraction area, a variable delivery pump having a movable flow-control member, yielding means for urging said flow-control member in a flow-increasing direction, an auxiliary cylinder, an auxiliary piston therein connected to said flow-control member and adapted to move the same in a flow-reducing direction, a four-way valve movable selectively into one of two positions to admit pressure fluid from said pump to said advancing area while releasing fluid from said retraction area, or vice versa, a two-way valve adapted in a first position to effect communication between said four-way valve and said advancing area and in a second position to interrupt communication between said advancing area and said four-way valve, means continuously effecting hydraulic communication between said advancing area and said auxiliary cylinder irrespective of the positions of said valves, means adapted in response to the travel of said main piston during its advancing stroke to shift said two-way valve into said first position, and means responsive to the travel of said main piston during its retraction stroke to shift said two-way valve into said second position.

WALTER ERNST.