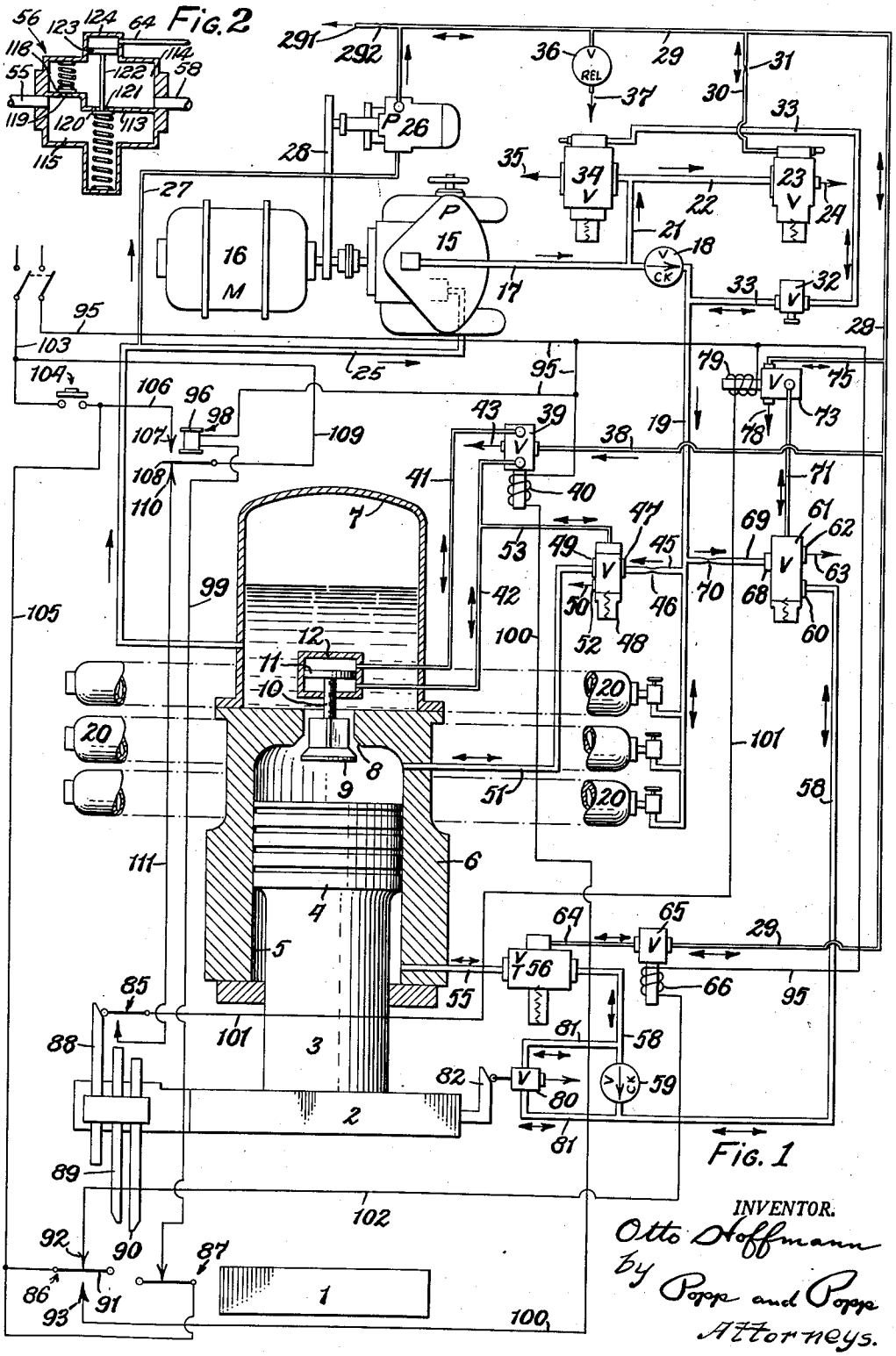
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PRESSURE ACCUMULATOR CIRCUIT FOR HYDRAULIC PRESSES

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PRESSURE ACCUMULATOR CIRCUIT FOR HYDRAULIC PRESSES

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This invention relates to improvements in a hydraulic circuit for hydraulic presses.

A primary object of the invention is to provide a hydraulic circuit particularly for heavy duty presses and which provides such a press with a short operating cycle.

Another object is to provide such a hydraulic circuit which produces a high speed pressing stroke, such high speed pressing or working stroke being desirable both to provide increased capacity of the press and also to reduce to a minimum the length of time the dies are in contact with hot work pieces thereby to prevent overheating of the dies.

Another important object is to provide such a hydraulic circuit for a heavy duty press having operating mechanisms which can be compactly arranged on the press, thereby to provide a self-contained heavy duty press unit.

Another object is to provide a hydraulic system for a press in which the hydraulic circuit is precharged to provide a reserve of potential energy operatively released during the pressing or working stroke of the press ram and recharged during all other phases of the operating cycle of the press.

Another object is to provide such a precharged hydraulic circuit which requires only a relatively small amount of power input which is employed essentially to recharge the circuit.

Another object is to provide such a hydraulic circuit in which shock is eliminated, particularly when the movable die engages the workpiece and on the return stroke of the ram.

Another object is to provide a hydraulic circuit for a hydraulic press in which the maximum pressure is applied during the entire pressing or working stroke.

Another object is to provide such a hydraulic circuit for hydraulic presses in which the working pressure can be readily adjusted to suit the particular work to be done.

Another object is to provide such a hydraulic circuit for hydraulic presses in which the desired working pressure is never exceeded.

Another object is to provide such a hydraulic circuit in which the raising of the ram at the end of the pressing stroke can be initiated either by a limit switch or by the pressure applied to the workpiece.

Another object is to provide such a hydraulic circuit which can be embodied in a press and adapted for selectively operating the press on a cycle which permits of inching under manual

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control, semi-automatic or single cycle, fully automatic, or multiple cycle.

Other objects and advantages of the invention will appear from the following description and drawing in which Fig. 1 is a diagrammatic representation of a hydraulic circuit embodying the present invention and applied to a heavy duty high speed press and showing a simplified electrical control circuit adapted for the semi-automatic or single cycle operation thereof, while Fig. 2 is a sectional view of the throttle valve.

The hydraulic circuit embodying the present invention can be used in connection with various kinds of presses and for the purpose of illustration is shown as used in connection with a hydraulic press of the downward pressure type. This press is shown in simplified diagrammatic form as having a lower stationary platen 1 cooperating with a vertically movable upper platen 2 secured to the lower end of a ram 3. This ram has an enlarged piston head 4 which works in the bore 5 of a closed stationary main cylinder 6. A closed reservoir or tank 7 is mounted on the upper end of the main cylinder 6, communication between this reservoir and the upper end of the bore 5 of the main cylinder being provided by an opening 8 under control of an upwardly closing prefill valve 9. This valve 9 is actuated through a piston rod 10 projecting upwardly from the prefill valve and connecting with a piston 11 which works in a closed stationary cylinder 12, this stationary cylinder being arranged in the reservoir or tank 7. Both the piston 11 and the main ram 3 are of the double acting type. However it will be seen that a separate pull back means could be provided for the main piston 4 and that the closed lower end of the cylinder 6 provides such a pull back means since liquid forced into the lower end of this cylinder raises the piston 4. The liquid in the tank 7 can be maintained under slight pressure by pressurizing the air in the upper part of this tank.

In accordance with the invention the hydraulic circuit is shown as comprising a main pump 15 of any suitable type, driven by an electric motor 16. The main pump 15 delivers liquid under pressure through a pump discharge line 17 which is operatively connected through a check valve 18 to a line 19 connecting with a plurality of gas filled bottles 20. Each of these bottles 20 contains a quantity of an inert gas such as nitrogen which is compressed to a relatively high initial pressure. The bottles 20 can be of any suitable type which establish pres-

sure communication between the gas in the bottles and the liquid in the line 19, it being preferred to employ such a bottle in which the gas and liquid are separated by a movable pressure transmitting member. Bottles of this type are commercially available.

The main pump 15 is unloaded during starting of the motor 16 and for this purpose branch lines 21 and 22 connect the main pump discharge line 17 with a normally open spring loaded pump unloading valve 23, which when open places the branch line 22 in communication with the valve outlet line 24 leading to the reservoir or tank 7. This return line 24, as well as similar return lines for other valves to be described hereinbelow, is represented by an arrow. The valve 23 is of any suitable conventional form in which control pressure acting against a spring closes the valve and cuts off this flow of liquid from the branch line 22 to the return line 24. A liquid supply line 25 connects the main pump 15 with the reservoir or tank 7.

The pressure for so closing the spring loaded pump unloading valve 23 is supplied from a pilot pump 26 driven through a belt 28 from the pump motor 16 and the discharge line 29 which is operatively connected by a branch line 30 with the pump unloading valve 23. This branch line 30 is provided with a restriction represented by the numeral 31, this restriction providing a time lag between the start of the pump motor 16 and the closing of the pump unloading valve 23. A liquid supply line 27 connects the pilot pump 26 with the liquid supply line 25 leading from the reservoir or tank 7. A branch line 291 having a restriction 292 connects the discharge line 29 with the reservoir or tank 7 and provides a means of relieving the pilot pressure in the discharge line 29 when the motor 16 is stopped.

The maximum operating pressure in the line 19 can be adjusted to the value desired. For this purpose an adjustable pressure relay valve 32 is arranged in a branch line 33 and connected at one end to the line 19 and at its opposite end being operatively connected with a normally closed spring loaded pump unloading valve 34 which when open places the branch line 22 in communication with the valve outlet line 35 leading to the reservoir or tank 7. The valve 34 is similar, except for being normally closed, to the valve 23 in that pressure admitted through the line 33 acts against a spring to open the valve 34 and permit the flow of liquid from the branch line 22 to the return line 35. Thus, when the pressure in line 19 exceeds the setting of the pressure relay valve 32, pressure is applied to the pump unloading valve 34 to open this valve and permit the main pump 15 to unload through the lines 21, 22 and 35. The discharge line 29 of the pilot pump 26 is provided with a relief valve 36 having a return line 37 to the tank or reservoir 7 and operating to prevent the outlet pressure of the pilot pump 26 from rising above a predetermined value.

The prefill valve 9 is actuated by pilot pressure derived from the pilot pump 26. For this purpose a branch line 38 connects the pilot pump discharge line 29 with the inlet of a four way pilot solenoid valve 39. When the winding 40 of this solenoid valve is de-energized its inlet line 38 is in communication with a control line 41 leading from one port of said pilot valve to the stationary cylinder 12 above the piston 11 and at the same time a control line 42 leading from another port of said pilot valve to the cylinder 12 below the piston 11 is in communication with a return line 43 leading to the tank or reservoir 7. Conversely, when the winding 40 of the four way pilot solenoid valve 39 is energized, its inlet line 38 is in communication with the line 42 and the line 41 is in communication with the return line 43.

In order to admit liquid under working pressure to the main cylinder 6 above the piston 4 of the ram 3, a branch line 45 having a restriction 46 connects the line 19 with the inlet 47 of a normally closed spring loaded working pressure valve 48. A line 51 connects a port 49 of this valve with the main cylinder 5 above the piston 4 of the ram 3. A return line 50 connects another port 52 with the reservoir or tank 7. When the valve 48 is closed there is no communication between the branch line 45 and the line 51 but communication is provided between the ports 49 and 52 so that liquid from the line 51 is able to flow through the return line 50 to the reservoir or tank 7. To establish communication between lines 45 and 51 the valve 48 is opened against the urging of its spring by pilot pressure admitted through a line 53 operatively connecting this valve with the line 42. So opening the valve 48 breaks communication between the lines 51 and 50. The working pressure valve 48 may be of any suitable conventional form.

To permit the ram 3 to descend, the liquid in the main cylinder 6 below the piston 4 of the ram is relieved through the line 55 which connects with a spring loaded throttling control valve 56, this liquid flowing through this valve to a line 58 containing a check valve 59 and leading to a port 60 of a spring loaded pull back valve 61. This liquid flows from the port 62 of this pull back valve through a return line 63 leading to the reservoir or tank 7.

The throttling valve 56 is illustrated in detail in Fig. 2 and is shown as being in the form of a two way check valve comprising a stationary casing having a horizontal central partition 113 providing an upper chamber 114 and a lower chamber 115. The line 58 connects with the upper chamber 114 and the lower chamber 115 is connected by the line 55 with the lower end of the bore 5 of the main cylinder 6. A spring loaded check valve 118 in the upper chamber 114 seats against an opening 119 through the partition 113 to prevent flow of liquid from the upper chamber 114 to the lower chamber 115 but to permit a restricted reverse flow when the pressure of its spring is overcome. A spring loaded check valve 120 in the lower chamber 115 seats against an opening 121 through the partition 113 to prevent flow of liquid from the lower chamber 115 to the upper chamber 114. This check valve 120 has a stem 122 connected with a piston 123 in a cylinder 124 formed in the casing of the throttling valve 56, this cylinder 124 communicating with the line 64. The check valve 118 permits a restricted flow of pull back liquid into the bore 5 and the flow of pull back liquid in the opposite direction is resisted by the spring loaded check valve 120, the spring being adjusted so as to close this check valve and counterbalance the weight of the ram 3 and its associated moving parts but opening to provide a throttled relief of pull back liquid from the bore 5 when working pressure is applied to the top of the piston 4. The spring loaded check valve 120 is opened against the urging of its spring by pilot pressure admitted through the line 64 operatively

connecting the throttling control valve 56 with the pilot pressure line 29 through a normally closed slow down solenoid valve 65 having a winding designated at 66. When the winding 66 is energized, the solenoid valve 65 opens and places lines 29 and 64 in communication with each other thereby to apply pilot pressure to the upper face of the piston 123. This pilot pressure thereby opens the spring loaded check valve 120 against the urging of its spring, thereby to place lines 55 and 58 in communication with each other.

Thus the throttling control valve 56 serves the purpose of holding up the moving weight when the main pump 15 is in neutral or not running, such moving weight being balanced by spring pressure against the spring loaded check valve 120. The throttling valve 56 serves the further purpose of slowing down the speed of the ram 3 for the working or pressing stroke of the ram. During the high speed approach of the closing stroke, the spring loaded check valve 120 of the throttling valve 56 is held open by pilot pressure which acts on the piston 123 against the urging of the spring of this check valve 120. Slowing down the descending ram 3 to pressing speed is accomplished by withdrawing the pilot pressure against the piston 123 of the throttling control valve 56 and forcing the liquid in the line 55 which is under a pressure exceeding that of the spring pressure of the spring loaded check valve 120 through this check valve against its spring pressure and into the line 58.

The spring loaded pull back valve 61 also has a port 68 connected by a line 69 having a restriction 70 with the line 19. This spring loaded pull back valve 61 is operated against the urging of its spring by pilot pressure admitted through a line 71 operatively connecting this valve with an outlet of a normally closed return solenoid valve 73. This valve 73 has an inlet connected by a line 75 with the pilot pump discharge line 29 and also has an outlet connected by a return line 78 leading to the reservoir or tank 1. The return solenoid valve 73 has a winding 79 which, when de-energized, places lines 71 and 78 in communication with each other and cuts off the pilot pressure line 75, and, when energized, places lines 75 and 71 in communication with each other and cuts off the return line 78.

To limit the upward movement or overtravel of the ram 3, a normally open shut-off valve 80 is arranged in a line 81 which at its opposite ends connects with line 58 and which bypasses the check valve 59. This normally open shut-off valve 80 is closed by a cam bar 82 moving with the movable platen 2 of the press. The cam bar 82 projects upwardly from its mounting and, in the elevated position of the press ram, is arranged to operatively engage and close the shut-off vlave 80.

The electrical circuit is shown as including three limit switches 85, 86 and 87 actuated, respectively, by three vertical cam rods 88, 89 and 90 moving with the movable platen 2 of the press. The cam rod 88 projects upwardly from its mounting and, in the elevated position of the press ram, is arranged to engage and open the initially open return limit switch 85. The rod 89 projects downwardly from its mounting and, in a depressed position of the press ram, is arranged to engage and actuate the slow down limit switch 86, the movable contact 91 of which is normally in contact with its fixed contact 92 and is moved downwardly during the final descending movement of the rod 89 into engagement with its fixed contact 93. The rod 90 projects downwardly from its mounting and, in the extreme depressed position of the ram, is arranged to engage and open the normally closed down or maximum stroke limit switch 87.

One side 95 of the main power line connects with the winding 49, 79 and 66 of each of the solenoid valves 39, 73 and 65, respectively, and also connects with the winding 96 of a holding relay 98. The other end of the winding 96 of this holding relay 98 is connected by a wire 99 with the fixed contact of the down or maximum stroke limit switch 87. The other end of the winding 40 of the close solenoid valve 39 is connected by a wire 100 with the lower fixed contact 93 of the slow down limit switch 86. The other end of the winding 79 of the return solenoid valve 73 is connected by a wire 101 with the movable contact of the return limit switch 85. The other end of the winding 66 of the slow down solenoid valve 65 is connected by a wire 102 with the upper fixed contact 92 of the slow down limit switch 86.

The other side 103 of the main power line is connected by a manually operable normally open close button 104 with a wire 105 connecting with the movable contacts of the slow down limit switch 86 and down or maximum stroke limit switch 87. This manually operable close button 104 also connects this side 103 of the main power line with a wire 106 connecting with the normally open fixed contact 107 of the relay 98. The armature 108 of this relay 98 is connected through the wire 109 directly with the side 103 of the main power line and its normally closed fixed contact 110 is connected through a wire 111 with the fixed contact of the return limit switch 85.

The above electrical circuit is adapted for single cycle or semi-automatic operation of the press wherein the operator actuates the close button 104 to effect each complete operating cycle. This electrical circuit is shown in simplified form for the purpose of illustrating one operative embodiment of the invention and it will be understood that in actual practice the press would have an electrical control circuit, permitting of inching and full automatic operation as well as the single cycle operation shown.

It will also be understood that the hydraulic circuit can include such unessential but desirable equipment as hand valves, relief valves, oil filters, oil coolers, oil temperature and pressure gauges, and the like, such elements being omitted from the embodiment illustrated. It will also be understood that the press will usually be provided with a hydraulically operated stripper mechanism which is operatively connected into the hydraulic circuit.

Operation

At the start of operation it is desirable that the full load upon the motor 16 be applied gradually and to this end the main pump 15 is unloaded when the motor is started. Thus, upon energizing the motor 16, the discharge from the main pump 15 passes through the main pump discharge line 17, branch lines 21 and 22, open spring loaded pump unloading valves 23 and through its return line, designated by the arrow 24, to the reservoir or tank 1 which is connected with the supply line 25 leading to the inlet of the main pump. At this time the liquid discharged by the main pump 15 cannot enter the spring loaded pump unloading valve 34 through the branch line 22 since this valve is closed.

Starting the motor 16 also starts the pilot pump 26 and the outlet pressure from this pump is applied from its discharge line 29 through the branch line 30 and restriction 31 to the now open spring loaded pump unloading valve 23. This closes the valve 23, the restriction 31 providing a sufficient time lag for the motor 16 to reach running speed before full load is applied to it. With the pump unloading valve 23 closed the pressure in the main pump discharge line 17 against the check valve 18 opens this check valve so that fluid is pumped into the line 19 for operation of the press including recharging the bottles 20.

In the event the pressure in the line 19 exceeds the maximum determined by the setting of the adjustable pressure relay valve 32, this valve admits liquid through its outlet line 33 to the spring loaded pump unloading valve 34 to open this valve against the urging of its spring. With this valve 34 so opened, liquid from the main pump discharge line 17 passes through the branch lines 21 and 22 to the return line 35 and is thereby returned to the reservoir or tank 7. At this time when the valve 34 is so opened the other spring loaded pump unloading valve 23 is closed. Thus the spring loaded pump unloading valves 34 and 23 together with their associated lines provide a hydraulic circuit which serves primarily to control the pressure in the line 19 and secondarily to unload the main pump 15 when starting the motor 16.

The operator then places the workpiece on the stationary lower platen 1 and manually closes the normally open close button 104. This establishes a circuit from the side 103 of the main power line through close button 104, wire 105, closed down or maximum strokelimit switch 87, winding 96 of holding relay 98 to the other side 95 of the main power line. The armature 108 of the now energized holding relay 98 is drawn into engagement with its fixed contact 107 thereby to establish through the wires 109 and 106 a bypass around the manually operated close button 104 and seal the circuit just described until broken at another point.

With the holding relay 98 so closed current passes from the side 103 of the main power line, through wire 109, armature 108 and fixed contact 107 of the holding relay 98, wires 106 and 105, movable contact 91 and fixed contact 92 of the slow down limit switch 86, wire 102, and winding 66 of the normally closed slow down solenoid valve 65 to the other side 95 of the main power line. Energization of the slow down solenoid valve 65 causes this valve to open and admit pilot pressure to work against the piston 123 of the spring loaded check valve 120 of the throttling control valve 56 and thereby open this check valve to place lines 29 and 64 in free flow communication with each other. Pilot pressure so applied to the piston 123 of the spring loaded control valve 120 causes this valve to open against the urging of its spring.

The now opened control valve 53 places the line 55 in communication with the line 58 and permits pull back liquid to flow from the main cylinder 6 below the piston 4 through line 55, open control valve 56, line 58 past the check valve 59, open spring loaded pull back valve 61 and return line 63, the latter returning the pull back liquid to the reservoir or tank 7. It will be noted that at the beginning of the descent of the ram 3 the shut off valve 80 is completely closed so that liquid flowing in the line 58 toward the pull back valve 61 must pass through the check valve 59. However, as the ram lowers the shut off valve 80 is permitted to open to a fully opened position by reason of the cam bar 82 lowering with the ram and this cam bar disengaging this valve so that the pull back liquid being exhausted from the main cylinder 6 can either pass the check valve 59 or flow through the now opened shut off valve 80.

During the descending movement of the ram 3 prefill liquid is supplied to the main cylinder 6 above the piston 4 from the reservoir or tank 7, the prefill valve 9 being open to permit such flow. The prefill liquid in this reservoir or tank 7 can be under pressure or not, as may be required to secure the desired prefilling speed. The prefill valve 9 is held open at this time through pilot pressure applied to the upper side of its piston 11 from the pilot pump discharge line 29, inlet line 38, and four way pilot solenoid valve 39 which is de-energized and has has its inlet line 38 in communication with its line 41 and its line 42 in communication with its return line 43 so that the liquid under the piston 11 can escape through the line 42, valve 39 and return line 43 to the tank or reservoir 7.

As soon as the ram 3 starts its descent it sets up the electrical circuit for return of the ram. This is effected by the cam rod 88 which on the start of the descent of the ram 3 released the initially open return limit switch 85 so that this switch closes. However, at this time the closing of this return limit switch 85 does not energize the winding 79 of the return solenoid valve 73 because at this time the holding relay 98 is energized so that its armature 108 is out of contact with its fixed contact 110 and therefore a closed circuit through the winding 79 is not established. Since this winding of the return solenoid 73 is not energized, pilot pressure continues to be cut off from the spring loaded pull back valve 61 so that pull back liquid continues to be discharged from its return line 63 to the reservoir or tank 7.

This descent of the ram 3 constitutes the high speed approach of the ram to the workpiece and is slowed down just before the die (not shown) carried by the upper movable platen 2 engages the workpiece. Slowing the ram down is effected by the cam rod 89 engaging the slow down switch 86 and moving its movable contact 91 out of engagement with the fixed contact 92 and into engagement with the fixed contact 93. Breaking the contact between the contacts 91 and 92 breaks the circuit through the winding 66 of the normally closed slow down solenoid valve 65 thereby cutting off pilot pressure to the spring loaded control valve 56. Such withdrawal of the pilot pressure from the control valve 56 permits the spring loaded check valve 120 of this control valve partially to close and thereby reduce the speed of descent of the ram by throttling the escape of pull back liquid from below the piston 4. The spring loaded valve 120 does not completely close at this time inasmuch as the pressure of the liquid in the line 55 exceeds that of the spring pressure against this spring loaded valve 120, this preponderating liquid pressure in the line 55 being due to the application of an increased force upon the upper end of the ram 3.

This increased pressure upon the upper end of the ram 3 is applied simultaneously with this throttling of the escape of pull back liquid by

the engagement of the contacts 91 and 93 of the slow down limit switch 86. This engagement establishes a circuit through the winding 40 of the four way pilot solenoid valve 39. Energization of this winding 40 operates the four way pilot solenoid valve 39 to break communication between the pilot pressure inlet line 38 and the line 41, establish communication between this line 41 and the return line 43 to the tank 7, and establish communication between the pilot pressure inlet line 38 and the line 42. Accordingly, pilot pressure is applied through line 42 to the under side of the piston 11 to raise and close the prefill valve 9, the liquid above this piston 11 escaping through the line 41, valve 39 and return line 43 to the reservoir or tank 7.

Pilot pressure so established in line 42 is also transmitted through branch line 53 to open the normally closed spring loaded working pressure valve 48. Opening this valve 48 permits liquid from the line 19 to flow through the branch line 45, restriction 46, valve 48 and through line 51 to the cylinder 6 above the ram. The restriction 46 provides a sufficient time lag to permit the prefill valve 9 to be closed before the liquid under working pressure is admitted to the main cylinder 6 through line 51.

It will particularly be noted that the liquid so admitted to the main cylinder 6 from the line 19 is under the maximum pressure built up in the bottles 20 and also in accordance with the setting of the adjustable pressure relay valve 32. It will also be noted that this pressure in the bottles 20 is not utilized until the ram so starts its pressing stroke so that the full reserve of potential energy stored in these bottles is operatively released during the pressing or working stroke.

This full pressure in the line 19 is continued to be applied to the ram 3 during its pressing or working stroke and until the cam rod 90 engages and opens the normally closed down or maximum stroke limit switch 87. Opening this switch 87 breaks the circuit through the winding 96 of the holding relay 98 thereby to disengage its armature 103 from the fixed contact 107 and to re-engage the armature with its fixed contact 110.

Breaking the contact between the armature 103 and fixed contact 107 of the relay 98 operates to cut off the flow of liquid under working pressure to the upper side of the ram 3 and also to open the prefill valve 9 so that upon thereafter raising the ram 3 by introducing pull back liquid under pressure to the under side of its piston 4 the liquid above the ram 3 can enter the reservoir or tank 7 through the passage 8.

Thus, breaking the contact between the armature 103 and fixed contact 107 of the relay 98 breaks the circuit through winding 40 of the four way pilot solenoid valve 39 thereby to establish communication between the lines 42, 53, and the return line 43 to the tank or reservoir 7, and to establish communication between the pilot pressure inlet line 38 and the line 41. Accordingly, pilot pressure is relieved from application to the normally closed spring loaded working pressure valve 48 by reason of the line 53 being so connected through the line 42 to the return line 43 to the tank or reservoir 7. Relieving the pilot pressure on the valve 48 permits this valve to shift thereby to cut off communication between the working pressure inlet line 45 leading from line 19 and the line 51 leading to the main cylinder 6, and establishing communication between line 51 from the main cylinder and the return line 50 to the tank or reservoir 7. Accordingly the application of working pressure to the upper end of the ram 3 is cut off, and the existing pressure therein relieved. At the same time pilot pressure is admitted to the cylinder 12 above the piston 11 to force this piston downwardly and open the prefill valve 9, the liquid below this piston escaping through the line 42 and return line 43 to the reservoir or tank 7. This action cannot occur however until the pressure above ram 3 is relieved.

Making contact between the armature 103 and fixed contact 110 of the relay 98 operates to admit pull back liquid under pressure to the main cylinder 6 below the piston 4 and thereby raise the ram 3.

Thus, this engagement of the armature 103 and fixed contact 110 of the relay 98 closes a circuit from the side 103 of main power line through wire 109, armature 103, fixed contact 110, wire 111, closed return limit switch 85, wire 101, and winding 79 of the normally closed return solenoid valve 73 to the other side 95 of the main power line. Energization of this normally closed return solenoid valve 73 places the pilot pressure branch line 75 into communication with the line 71 leading to the spring loaded pull back valve 61. The pilot pressure so applied to this valve 61 operates this valve against the pressure of its spring to break communication between the line 58 and return line 63 to the reservoir or tank 7 and to establish communication between the line 58 and the branch line 69 leading from the line 19. When the valve 61 is so operated, liquid under the maximum working pressure passes from line 19, through branch line 69 and restriction 70, valve 61, line 58, bypass line 81 and the now open shut-off valve 80, throttling control valve 56 and line 55 to the main cylinder 6 below the piston 4. Accordingly, the ram 3 is lifted or returned, the liquid above this ram flowing past the open prefill valve 9 into the tank or reservoir 7. It will be noted that the restriction 70 in the branch line 69 provides a sufficient time lag to permit the working pressure against the top of the ram 3 to be relieved and the prefill valve 9 to open before pull back liquid under pressure is so applied to the under side of the piston 4.

The ram 3 continues to rise until the cam rod 93 reengages and opens the return limit switch 85, this engagement being slightly in advance of the engagement of the cam bar 82 with the shut-off valve 80. Opening the return limit switch 85 de-energizes the winding 79 of the return solenoid valve 73 thereby to break communication between the pilot pressure branch line 75 and the line 71 leading to the spring loaded pull back valve 61. So relieving the application of pilot pressure to the valve 61 permits this valve to break communication between the branch line 69 and line 58 and re-establish communication between line 58 and the return line 63. So breaking communication between lines 69 and 58 terminates the flow of pull back liquid under pressure to the main cylinder 6 and hence stops the return movement of the ram. So re-establishing communication between lines 58 and 63 re-establishes the condition of the spring loaded pull back valve 61 for another cycle of operation.

The cam bar 82 then engages and closes the shut-off valve 80 due to overtravel of the ram 3 to re-establish the condition of this valve for another cycle of operation, the weight of the moving parts again being supported by the spring loaded check valve 120 in the throttling control valve 56

as previously described. This cycle is then repeated as above described. It will be noted that at the end of each cycle all of the solenoid valves are de-energized preparatory for the next operating cycle.

To illustrate the advantages of the hydraulic circuit, particularly in respect to providing a heavy duty press with a short operating cycle, a 600-ton press embodying this circuit has been constructed and which works at 20 strokes per minute, this including a closing stroke of 2 inches, a pressing stroke of .5 inch and also an allowance of time for loading and unloading which takes up almost half of the three-second cycle. This extremely rapid cycle for a press of this capacity is due primarily to the application of stored power at a particular point in the operation of the press, namely, during its pressing or working stroke. Thus, the pressure stored in the bottles 20 is applied to the ram at the start of the .5 inch pressing or working stroke and is cut off at the end of its return stroke, the total time for these strokes being less than half a second and these bottles being recharged during the remaining time of the operating cycle. This efficient utilization of the stored power in the bottles 20 so provides an extremely high operating speed in a heavy duty hydraulic press with a minimum horse power input, the pressing speed of the present circuit exceeding any speed heretofore attained with presses of such capacity in hydraulic presses. It provides the advantage of speed of mechanical presses with the advantages such as constant pressure during the pressing or working stroke, of hydraulic presses, and with a minimum power input.

I claim:

1. In a self-contained hydraulic press unit, the combination comprising a cylinder having a bore, a piston arranged in said bore, pull back means associated with said piston, a ram movable by said piston and pull back means successively through closing, pressing and return strokes, a liquid reservoir in communication with said bore for introducing prefill liquid therein during the closing stroke of said ram, a prefill valve operative to break communication between said reservoir and bore, a constantly operating pump for the working liquid, a discharge line connecting the outlet of said pump with said bore for introducing working liquid therein during the pressing stroke of said ram, a working pressure valve in said discharge line, a container individually associated with said discharge line and charged with compressed gas in pressure transmitting relation with the working liquid in said discharge line between said pump and working pressure valve whereby said container is recharged through pressure derived from the working liquid supplied by said pump, a pull back line connecting said discharge line, between said pump and working pressure valve, with said pull back means for applying pull back liquid to said pull back means during the return stroke of said ram, a pull back valve in said pull back line, means arranged to permit the withdrawal of pull back liquid from said pull back means during said closing and pressing strokes, means arranged to close said prefill valve and open said working pressure valve and operative at the beginning of said pressing stroke, means operative at the end of said pressing stroke and arranged to close said working pressure valve to permit recharging of said container by said pump and arranged to open said prefill valve, and means arranged to open and close said pull back valve and operative to open said pull back valve at the beginning of said return stroke and to close said pull back valve at the end of said return stroke.

2. In a self-contained hydraulic press unit, the combination comprising a cylinder having a bore, a piston arranged in said bore, pull back means associated with said piston, a ram movable by said piston and pull back means successively through closing, pressing and return strokes, a liquid reservoir in communication with said bore for introducing prefill liquid therein during the closing stroke of said ram, a prefill valve operative to break communication between said reservoir and bore, a constantly operating pump for the working liquid, a discharge line connecting the outlet of said pump with said bore for introducing working liquid therein during the pressing stroke of said ram, a working pressure valve in said discharge line, a container individually associated with said discharge line and charged with compressed gas in pressure transmitting relation with the working liquid in said discharge line between said pump and working pressure valve whereby said container is recharged through pressure derived from the working liquid supplied by said pump, a first pull back liquid line connected to said discharge line between said pump and working pressure valve, a second pull back liquid line connected to said pull back means for alternately withdrawing pull back liquid therefrom during said closing and pressing strokes and introducing pull back liquid thereto during said return stroke, a return line, pull back valve means operatively connecting said first and second pull back liquid lines and return line, means arranged to actuate said pull back valve means to establish communication between said second pull back liquid line and said return line during said closing and pressing strokes and to establish communication between said first and second pull back liquid lines during said return stroke, a throttling control valve in said second pull back liquid line, means arranged to open said throttling control valve during said closing stroke, means arranged to close said throttling control valve to a throttling position during said pressing stroke to slow down the speed of said ram during said pressing stroke, means arranged to close said prefill valve and open said working pressure valve and operative at the beginning of said pressing stroke, and means operative at the end of said pressing stroke and arranged to close said working pressure valve to permit recharging of said container by said pump and also arranged to open said prefill valve.

3. In a press including a cylinder having a bore, a ram arranged in said bore and movable through closing and pressing strokes, a liquid reservoir arranged to communicate with said bore for introducing prefill liquid therein during the closing stroke of said ram, and a prefill valve operative to establish and break said communication between said reservoir and bore, the combination therewith of a hydraulic circuit, comprising a constantly operating pump for the working liquid, a discharge line connecting the outlet of said pump with said bore for introducing working liquid therein during the pressing stroke of said ram, a working pressure valve in said discharge line, a container charged with compressed gas in pressure transmitting relation with the working liquid in said discharge line between said pump and working pressure valve whereby said container is recharged through pressure de-

rived from the working liquid supplied by said pump, a pilot valve having a pair of lines connected with said prefill valve to actuate said prefill valve, and a line connecting one of said pair of lines with said working pressure valve to actuate said working pressure valve in response to the actuation of said prefill valve.

4. In a press including a cylinder having a bore, a ram arranged in said bore and movable through closing and pressing strokes, a liquid reservoir arranged to communicate with said bore for introducing prefill liquid therein during the closing stroke of said ram, and a prefill valve operative to establish and break said communication between said reservoir and bore, the combination therewith of a hydraulic circuit, comprising a constantly operating pump for the working liquid, a discharge line connecting the outlet of said pump with said bore for introducing working liquid therein during the pressing stroke of said ram, a working pressure valve in said discharge line, a container charged with compressed gas in pressure transmitting relation with the working liquid in said discharge line between said pump and working pressure valve whereby said container is recharged through pressure derived from the working liquid supplied by said pump, a pilot valve having a pair of lines connected with said prefill valve to close and open said prefill valve at the beginning and end, respectively, of said pressing stroke, and a line connecting one of said pair of lines with said working pressure valve to open and close said working pressure valve through power derived from said pilot valve.

5. In a press including a main cylinder having a bore, a ram arranged in said bore and movable through closing and pressing strokes, a liquid reservoir in communication with said bore, a normally open prefill valve operatively arranged between said reservoir and bore, and a piston and cylinder mechanism arranged to operate said prefill valve to close said prefill valve and thereby break communication between said reservoir and bore, the combination therewith of a hydraulic circuit comprising a constantly operating pump, a discharge line connecting the outlet of said pump with said bore for introducing working liquid therein during the pressing stroke of said ram, a normally closed working pressure valve arranged in said discharge line, a container charged with compressed gas in pressure transmitting relation with the working liquid in said discharge line between said pump and working pressure valve whereby said container is recharged through pressure derived from the working liquid supplied by said pump, and means arranged to open said working pressure valve in response to the closing of said prefill valve, comprising a pilot valve having its inlet connected to a source of fluid under pressure, a line connected to the outlet of said pilot valve and operatively connected with said piston and cylinder mechanism, a second line connected to said last line and operatively connected to said working pressure valve for opening the same and means arranged to open said pilot valve.

6. In a press including a main cylinder having a bore, a ram arranged in said bore and movable through closing and pressing strokes, a liquid reservoir in communication with said bore, a normally open prefill valve operatively arranged between said reservoir and bore and a double acting piston and cylinder mechanism arranged to open and close said prefill valve, the closing of said prefill valve breaking communication between said reservoir and bore, the combination therewith of a hydraulic circuit comprising a constantly operating pump, a discharge line connecting the outlet of said pump with said bore for introducing working liquid therein during the pressing stroke of said ram, a normally closed spring loaded working pressure valve arranged in said discharge line, a container charged with compressed gas in pressure transmitting relation with the liquid in said discharge line between said pump and working pressure valve whereby said container is recharged through pressure derived from the working liquid supplied by said pump, and means arranged to open said spring loaded working pressure valve in response to the closing of said prefill valve, comprising a solenoid valve having an inlet, two ports and a drain outlet, means connecting said inlet to a source of fluid under pressure, a first line connecting one of said ports to said piston and cylinder mechanism for applying fluid against one side of said piston to open said prefill valve and also for withdrawing fluid from said one side of said piston to permit said prefill valve to close, a second line connecting the other of said ports to said piston and cylinder mechanism for applying fluid against the other side of said piston to close said prefill valve and also for withdrawing fluid from said other side of said piston to permit said prefill valve to open, the normal condition of said solenoid valve being such as to establish communication between said inlet and said first line and to establish communication between said drain outlet and said second line, a third line connecting said second line operatively with said spring loaded working pressure valve for opening it against the urging of its spring, and electrical means arranged to operate said solenoid valve thereby to establish communication between said inlet and said second line and between said drain outlet and said first line whereby said prefill valve is closed and said spring loaded working pressure valve is opened.

7. In a press including a cylinder having a bore, a piston arranged in said bore, pull back means associated with said piston, a ram movable by said piston and pull back means successively through closing, pressing and return strokes, a liquid reservoir in communication with said bore during said closing and return strokes, a prefill valve operative to break communication between said reservoir and bore during said closing stroke, a constantly operating pump for the working liquid, a discharge line connecting the outlet of said pump with said bore for introducing working liquid therein during said pressing stroke, a container charged with compressed gas in pressure transmitting relation with the working liquid in said discharge line whereby said container is recharged through pressure derived from the working liquid supplied by said pump, a spring loaded pull back valve having an inlet connected with said discharge line, a return line connected with said pull back valve, pull back liquid lines connecting said pull back valve with said pull back means and normally establishing communication between said return and pull back liquid lines, a control line operatively connecting said pull back valve with a source of fluid under pressure for actuating said pull back valve against the urging of its spring to break the normal communication between said return and pull back liquid lines and to establish communi-

cation between said inlet and said pull back liquid lines, a normally closed control valve in said control line, and means arranged to open said control valve at the beginning of said return stroke.

8. In a press including a cylinder having a bore, a piston arranged in said bore, pull back means associated with said piston, a ram movable by said piston and pull back means successively through closing, pressing and return strokes, a liquid reservoir in communication with said bore during said closing and return strokes, a prefill valve operative to break communication between said reservoir and bore during said closing stroke, a constantly operating pump for the working liquid, a discharge line connecting the outlet of said pump with said bore for introducing working liquid therein during said pressing stroke, a container charged with compressed gas in pressure transmitting relation with the working liquid in said discharge line whereby said container is recharged through pressure derived from the working liquid supplied by said pump, a pull back liquid line connecting said discharge line with said bore on the side of said piston opposite from said prefill valve, pull back valve means operatively associated with said pull back liquid line and arranged to permit the withdrawal of pull back liquid from said pull back means through said pull back liquid line during said closing and pressing strokes and to introduce pull back liquid into said pull back means from said discharge line during said return stroke, a spring loaded throttling control valve arranged in said pull back liquid line between said pull back valve means and said pull back means and operative to permit the unrestricted flow of pull back liquid into said pull back means and operative to throttle the flow of pull back liquid from said pull back means, a control line operatively connecting said spring loaded throttling control valve with a source of fluid under pressure for opening said throttling valve against the urging of its spring, a normally closed control valve in said control line, and means arranged to open said control valve during said closing stroke.

9. In a self-contained hydraulic press unit, the combination comprising a main cylinder having a bore, a main piston arranged in said bore, pull back means associated with said piston, a ram movable by said main piston and pull back means successively through closing, pressing and return strokes, a liquid reservoir in communication with said bore, a normally open prefill valve operatively arranged between said reservoir and bore, a double acting piston and cylinder mechanism arranged to open and close said prefill valve, the closing of said prefill valve breaking communication between said reservoir and bore, a constantly operating pump for the working liquid, a discharge line connecting the outlet of said pump with said bore on the side of said main piston adjacent said prefill valve for introducing working liquid during the pressing stroke of said ram, a normally closed spring loaded working pressure valve arranged in said discharge line, a container charged with compressed gas in pressure transmitting relation with the liquid in said discharge line between said pump and working pressure valve whereby said container is recharged through pressure derived from the working liquid supplied by said pump, a source of fluid under pressure, a four way pilot valve having an inlet, two ports and a return line, means connecting said inlet with said source; a first line connecting one of said ports to said piston and cylinder mechanism for applying said fluid against one side of said piston to open said prefill valve and also for withdrawing fluid from said one side of said piston to permit said prefill valve to close, a second line connecting the other of said ports to said piston and cylinder mechanism for applying said fluid against the other side of said piston to close said prefill valve and also for withdrawing fluid from said other side of said piston to permit said prefill valve to open, the normal condition of said four way pilot valve being such as to establish communication between said inlet and said first line and to establish communication between said return line and said second line; a third line connecting said second line operatively with said spring loaded working pressure valve for opening it against the urging of its spring, means operative at the beginning of said pressing stroke and arranged to operate said four way pilot valve to establish communication between said inlet and said second line and between said return line and said first line whereby said prefill valve is closed and said spring loaded working pressure valve is opened, a spring loaded pull back valve having an inlet connected with said discharge line between said pump and working pressure valve, said pull back valve also having a return line and a port connected with said pull back means and normally establishing communication between said return line and said pull back valve port; a fourth line operatively connecting said pull back valve with said source for actuating said pull back valve against the urging of its spring to break the normal communication between said return line and said pull back valve port and to establish communication between said pull back valve inlet and said pull back valve port connected with said pull back means, a normally closed return valve in said fourth line, means arranged to open said return valve at the beginning of said return stroke, a spring loaded throttling control valve operatively arranged in the connection between said pull back valve and said pull back means and operative to permit the unrestricted flow of pull back liquid into said pull back means and operative to throttle the flow of pull back liquid from said pull back means; a fifth line operatively connecting said spring loaded throttling control valve with said source for opening said throttling control valve against the urging of its spring, a normally closed slow down valve in said fifth line; and means arranged to open said slow down valve during said closing stroke.

10. In the press including a main cylinder having a bore, a ram arranged in the said bore and movable through closing and pressing strokes, a liquid reservoir in communication with said bore, a normally open prefill valve operatively arranged between said reservoir and bore, and a piston and cylinder mechanism arranged to operate said prefill valve to close said prefill valve and thereby break communication between said reservoir and bore, the combination therewith of a hydraulic circuit comprising a constantly operating pump, a discharge line connecting the outlet of said pump with said bore for introducing working liquid therein during the pressing stroke of said ram, a normally closed working pressure valve arranged in said discharge line, a container charged with compressed gas in pressure transmitting relation with the working

liquid in said discharge line between said pump and working pressure valve whereby said container is recharged through pressure from the working liquid supplied by said pump, and means arranged to open said working pressure valve in response to the closing of said prefill valve, comprising a pilot valve having its inlet connected to a source of fluid under pressure, a return line connected with said pilot valve, a first control line connected to one port of said pilot valve and operatively connected with said piston and cylinder mechanism on the side of said piston and cylinder mechanism adjacent said prefill valve, a second control line connected to another port of said pilot valve and operatively connected with said piston and cylinder mechanism on the side of said piston and cylinder mechanism remote from said prefill valve, means arranged to actuate said pilot valve to place said second control line in communication with said return line, and a third control line connected to said first control line and operatively

connected with said working pressure valve for opening the same.

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