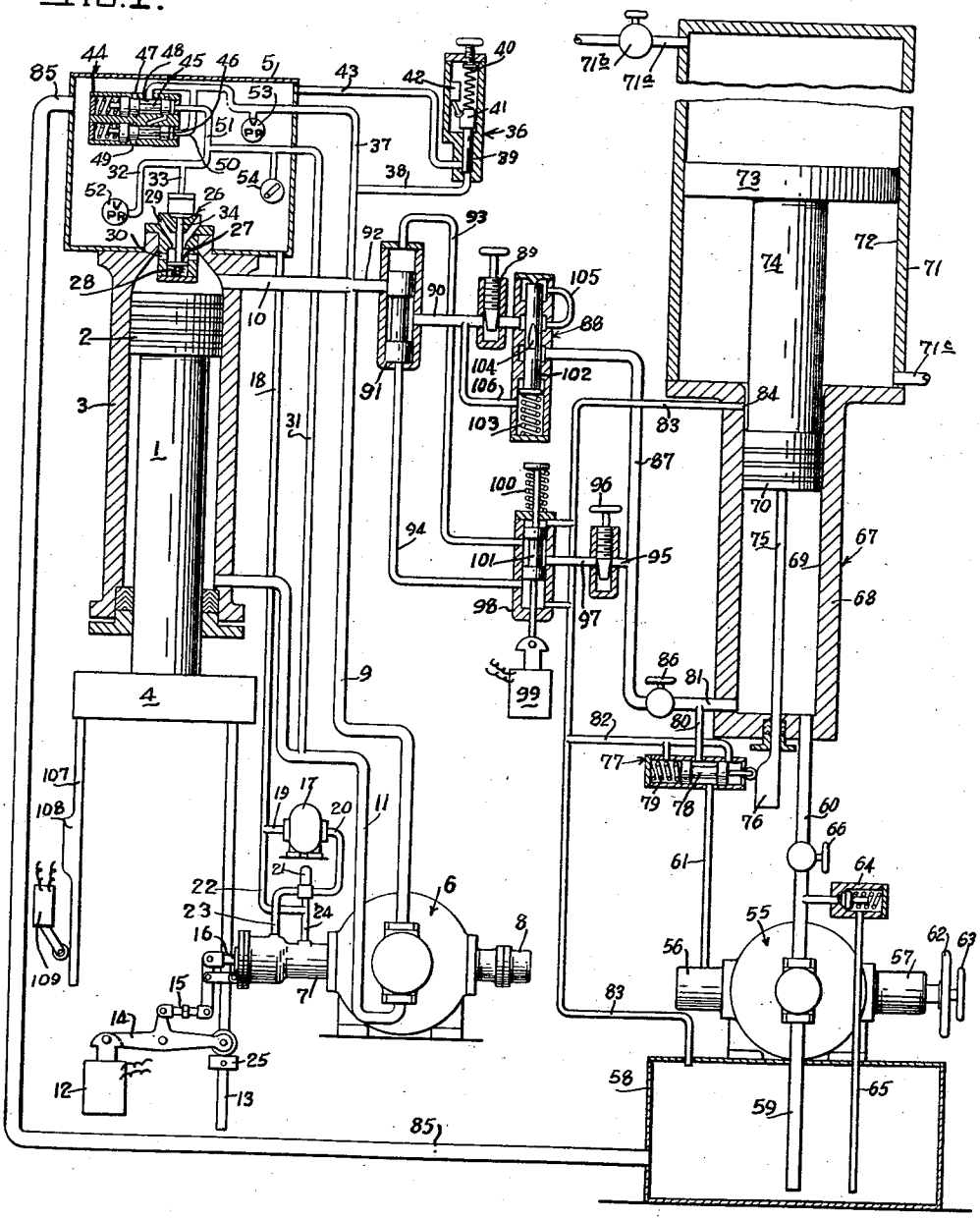
Feb. 29, 1944. W. ERNST 2,343,139

HIGH SPEED FORGING PRESS

Original Filed Jan. 15, 1940 4 Sheets-Sheet 1

FIG. 1.



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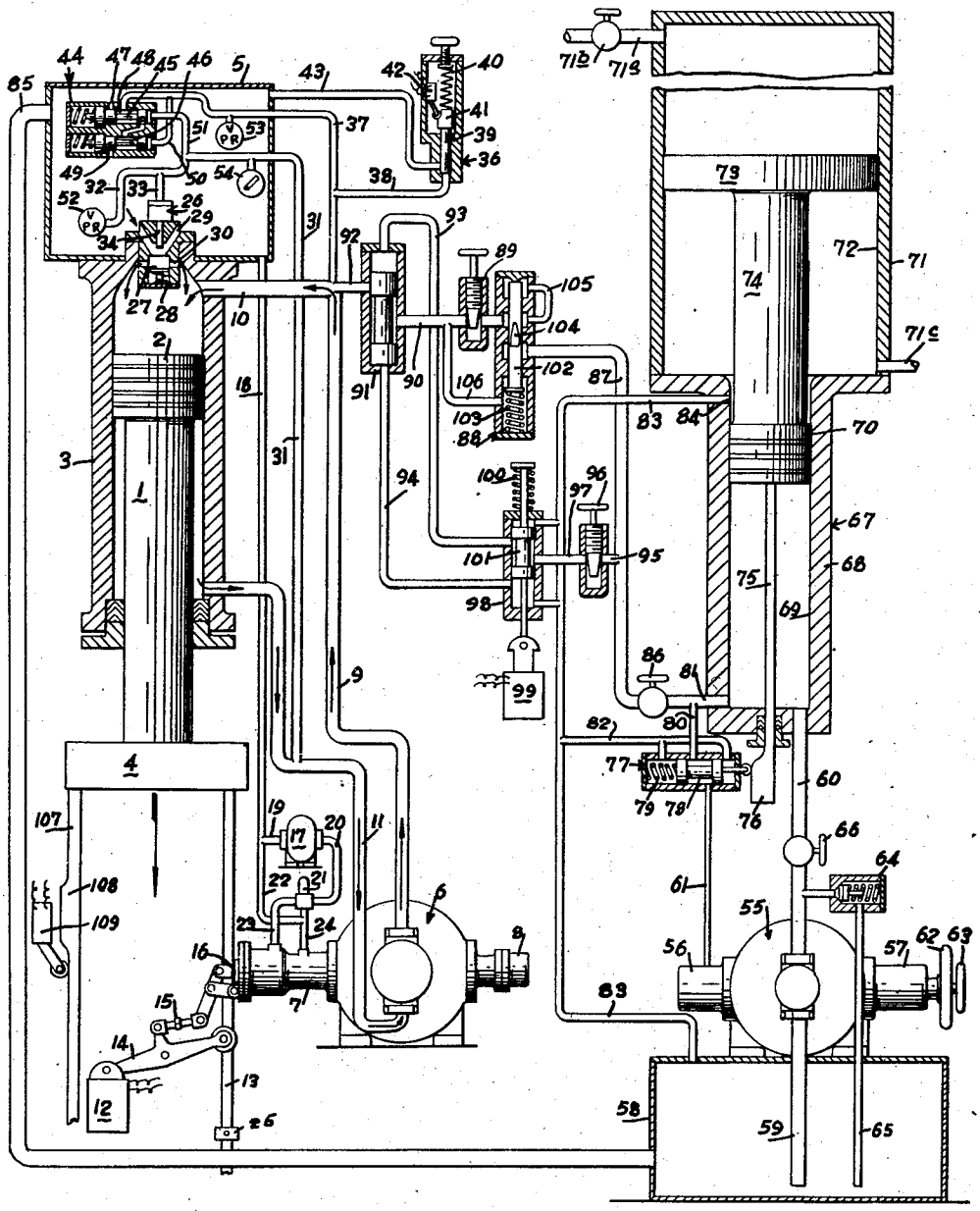
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Feb. 29, 1944. W. ERNST 2,343,139

HIGH SPEED FORGING PRESS

Original Filed Jan. 15, 1940 4 Sheets-Sheet 2

FIG. 2.



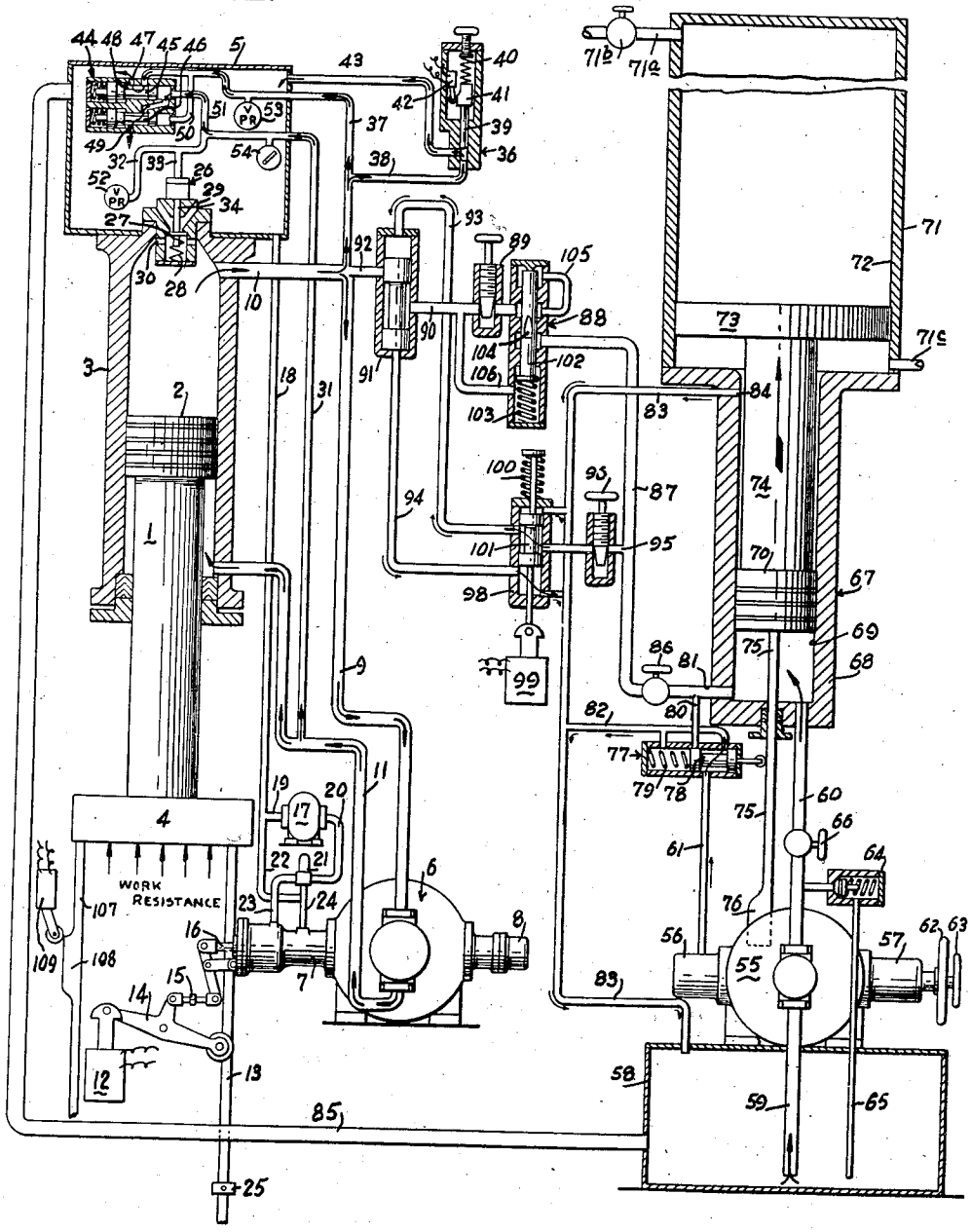
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Feb. 29, 1944. W. ERNST 2,343,139

HIGH SPEED FORGING PRESS

Original Filed Jan. 15, 1940 4 Sheets-Sheet 3

FIG. 3.



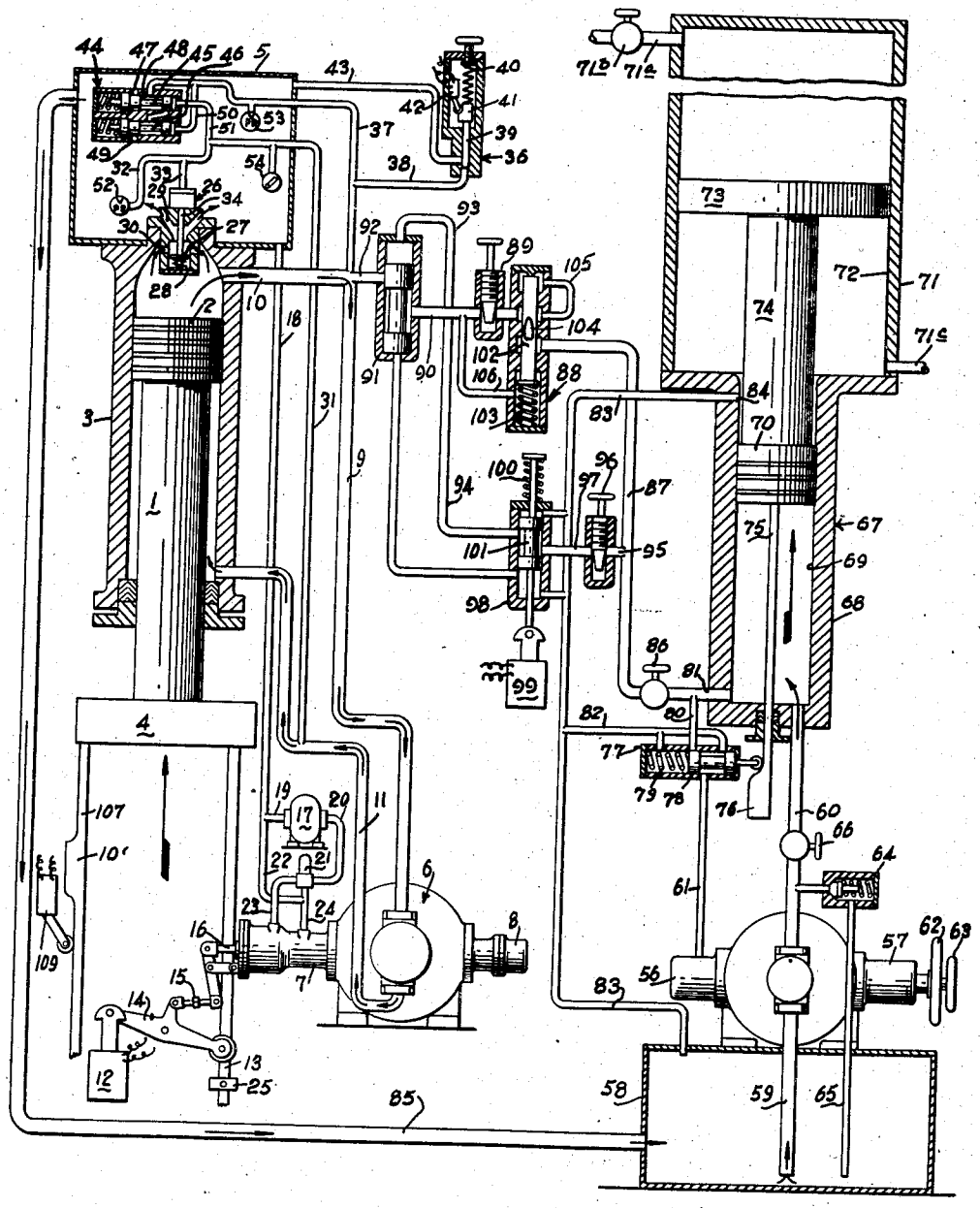
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Feb. 29, 1944. W. ERNST 2,343,139

HIGH SPEED FORGING PRESS

Original Filed Jan. 15, 1940 4 Sheets-Sheet 4

FIG. 4.



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Patented Feb. 29, 1944 2,343,139

UNITED STATES PATENT OFFICE

2,343,139

HIGH SPEED FORGING PRESS

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

Original application January 15, 1940, Serial No. 313,852. Divided and this application July 17, 1941, Serial No. 402,779

6 Claims. (Cl. 103—38)

The primary object of the present invention is to provide a means and method for operating a press where a relatively long working stroke of the press is necessary at relatively high speeds in order to economize time in the cycle of operations and where the final stroke of the press must be at speeds as high as the initial speed and at high pressures.

It is an object of this invention to provide a press, for such purposes as forging of steels, injection molding, die casting and the like. Heretofore where a relatively long working stroke at high pressures has been necessary, particularly in connection with forging presses, it has necessitated the use of a very large operating system of hydraulic accumulators, the first cost of which was prohibitive. Also, due to the relatively short portion the working cycle is of the total cycle of operations the system was highly inefficient.

The object of this invention is to provide a movement to the work at low pressure and high speed, giving a rapid traverse stroke; and to thereafter provide continued high speed at high pressure in order to impart tremendous pressures to the work, preferably without sudden shock, as is required in the case of forging metal billets, compressing plastics, etc.

Another object of this invention is to secure the advantages of a closed circuit with a reversible pump so that the direction of movement can be reversed without shock while securing the advantages of sudden high pressure. Thus shock is eliminated at the end of the reverse of the stroke which is characteristic of the accumulator type of press.

It is a further object to protect the press and the entire system against the accidental development of undue pressures, by the provision of safety valves at the necessary points in the system.

The press of this invention is especially intended for operations in which it is desirable or imperative to execute a relatively long high pressure stroke at high speed. Examples of such operations are found abundantly in forging, injection molding, or die casting. A specific example taken from the field of power forging, is the making of long steel shells. In this case a billet, heated to the correct temperature, is placed in the cavity of the lower die member, the first of two or more pressing movements being immediately thereafter initiated. This first movement might, for example, bring the upper male die member into the cavity of the lower die member to press the heated billet downwardly, forcing it to assume the shape of the lower portion of the cavity. The length of stroke necessary to accomplish this operation might be from several inches to more than a foot, depending on the particular workpiece in process. At any rate, the stroke must be executed rapidly, to prevent too great cooling of the part, in view of further pressing strokes yet to be performed.

The first male die member must then be withdrawn, again at a high rate of speed, and a second die member moved into place. This done, another stroke of the press is effected, either by manual or automatic control means, for example to form the interior of the shell by displacing some of the previously formed metal upwardly into the space between the two die halves. This operation, although requiring high pressures acting through a long stroke, must as before, be performed with great rapidity, to prevent the cooling of the shell to the point of shrinking upon the punch. Similarly, any subsequent pressing strokes will require rapid press action, the more numerous and the deeper these are, the more imperative becoming the high speed.

It is to meet the requirements of such a pressing operation, and to do this with economy of equipment and space, and with smoothness and efficiency, that this press has been invented.

This case is a division of my prior application Serial No. 313,852 filed January 15, 1940, and entitled "High speed forging press."

Referring to the drawings:

Figures 1 to 4 are diagrammatic views of the press and its operating system, showing the significant stages of a pressing operation.

Figure 1 illustrates the idling stage of the press and system, preparatory to a working stroke.

Figure 2 illustrates the initial stage of a working stroke, in which the press platen is caused to approach the work at a rapid rate, and under no pressure.

Figure 3 illustrates the reversing stage, the platen having completed its work, and the press controls being operative to initiate its return.

Figure 4 illustrates the stage in which the platen is returning to its idling position, and the auxiliary pressure system is storing working energy for the subsequent pressing cycle.

Referring in detail to Figures 1 to 4 of the drawings, the numeral 1 designates the pressing plunger of a hydraulic press, having at its upper end the double-acting piston 2. This piston reciprocates within the cylinder 3. At the lower

end of the plunger 1 is mounted a platen 4 upon which, in turn, is mounted the upper member of any suitable work-engaging means, such as a die or injection plunger. Disposed above the cylinder 3 and mounted thereon is a reservoir 5 adapted to store part of the fluid medium by which the press is operated.

The movement of the platen 4, and the pressures exerted by it upon the work, are determined by two independent pressure generating systems, and by a third interconnecting hydraulic control system. There are thus three distinct, but interrelated, hydraulic systems provided for the control of the press: a primary pressure system, a secondary or auxiliary pressure system, and an interconnecting control system. For the purpose of making clear the separate actions of these systems, they will first be described under separate headings.

Primary Pressure System

The primary pressure system is of the closed type and is operative throughout the entirety of a pressing cycle. It derives its flow of pressure fluid from the pump 6, which is of the reversible, variable delivery type, capable of generating high pressures. Preferably the controls for the shift ring of this pump consist of a pilot cylinder 7 and a self-centering spring cylinder 8, the design of which is well known, and does not constitute a part of the present invention.

The pump 6 delivers fluid to the differential areas of the press piston 2 in accordance with the setting of its shift ring. That is, the pump may deliver through lines 9 and 10 to the main pressing area of piston 2, withdrawing fluid from the push-back area through line 11, and thus effect a downward stroke of the piston; or, it may deliver into line 11, withdrawing from lines 9 and 10, and thus effect the reverse or upward stroke of the piston, depending upon the setting of the shift ring to the right or left of the center of the pump.

The position of the shift ring is primarily determined by the action of the operating solenoid 12 and the platen-actuated control rod 13, which transmit their respective motions through the lever 14 and linkage 15 to the pilot plunger 16. The reciprocation of this pilot plunger is in turn transmitted to the shift ring of the pump through the hydraulically actuated piston within cylinder 7, this piston being adapted to move directly, in direction and extent, with the pilot plunger.

The source of fluid pressure for this servomotor action is the constant delivery pilot pump 17, which draws fluid from the reservoir 5 through lines 18 and 19, discharging it through line 20 to one of the ports of a relief valve 21. Since the requirement of the servomotor for operating fluid is intermittent, as determined by solenoid 12 and control rod 13, this relief valve normally bypasses the discharge of pilot pump 17 into line 22 and back to the suction side of the pump through line 19. When, however, the control elements 12 and 13 act to cause movement of the pilot plunger 16 in either direction, fluid pressure within the servomotor is momentarily lowered, and the spring within the relief valve 21 moves the valve plunger to close the passage between lines 20 and 22. This results in directing the output of the pilot pump into the servomotor through line 23, effecting the required movement of the pump shift ring. The exhaust of fluid from the servomotor is by way of lines 24 and 22, either to pump 17 or reservoir 5.

When a downward, pressing stroke of piston 2 is to be effected, the solenoid 12 is energized (by means to be hereinafter described), its resultant motion (see Figure 2) being transmitted to the shift ring of pump 6 through the servomotor as described above, the pump then supplying fluid to line 9, and withdrawing it from line 11. When the pressing stroke thus initiated has been completed, the solenoid is de-energized (see Figure 3) and the pump is shifted to reverse its delivery by means of a spring within the servomotor, thus to effect an upward, return motion of the piston 2. As this piston nears the limit of its upward travel, the control rod 13, which is carried by platen 4, acts through an adjustable collar 25 to move lever 14 and ultimately the pump shift ring to their neutral positions, in which both pump 6 and piston 2 are caused to idle. Should any leakage of fluid occur to permit piston 2, with plunger 1 and platen 4, to descend of their own weight, control rod 13 and collar 25 will correspondingly descend, permitting the pump to again deliver to the push-back side of piston 2, restoring it to its idling position. This condition of the press is shown in Figure 1.

In addition to the press controls thus far described, there are provided certain other controls, one of which is a surge valve, generally designated 26. This valve is situated in the upper wall of cylinder 3, between the fluid reservoir 5 and the pressing area of piston 2, its purpose being to open a direct passage between this area and the fluid in the reservoir at certain stages of a pressing cycle. For example, when piston 2 and platen 4 move downwardly at the beginning of a pressing cycle, they do so under the influence of gravity, and at a rate determined by the suction of the pump 6 drawing fluid from the lower end of press cylinder 3. As the area in this end of the cylinder is relatively small, being only as large in cross section as the push-back side of piston 2, the piston tends to travel downwardly at a speed considerably greater than that at which the pump 6 delivers fluid through lines 9 and 10 to the upper, pressing side of the piston 2. This tendency creates a suction in the space above piston 2, which suction draws the valve member 27 downwardly against the spring 28, opening a passage between the fluid in reservoir 5 and the space above piston 2 by way of ports 29 and 30. The space above the piston is thus filled as rapidly as the pump 6 can remove fluid from the lower end of cylinder 3, making the advance of the platen towards the work as rapid as possible.

As soon as the platen 4, or the work-engaging member carried by it, contacts the work, pressure is developed in the upper end of cylinder 3 above piston 2, closing the surge valve 26 by moving the member 27 upwardly to cut off the passage between ports 29 and 30. The valve remains in this state until the reverse motion of the platen is begun, at which time it again opens, although by a different action than previously. As the piston 2 is driven upwardly by fluid pressure bearing against its push-back area, this pressure is communicated by the lines 31, 32 and 33 to the head of a plunger 34 in the upper part of the surge valve 26. The plunger is moved downwardly against the compression of spring 35, its lower extremity striking the upper surface of the valve member 27, forcing it open against spring 28. This opening of the surge valve again assists in a rapid motion of piston 2, in this instance by providing a free passage into the reservoir for fluid above the piston in excess of that

required by pump 6 to fill the push-back area of cylinder 3.

At the moment of reversal of platen 4, two other control valves are operative. One of these, the tonnage control valve, is designated generally 36. This valve, in fact, initiates the reversal of the platen by causing the de-energization of the solenoid 12 upon the attainment of the desired pressure upon the work. This pressure is communicated to the valve through lines 37 and 38, which are branches of the main pressure line 10 leading to the area above piston 2. From line 38 the pressure is directed against the end of the plunger 39, lifting it in opposition to the force exerted by a compression spring 40. This movement of plunger 39 is transmitted to a cam 41 carried at its upper end, the cam being adapted to trip a normally closed limit switch 42, in series with the contactor circuit for the solenoid 12. The valve 36 is maintained in this position as long as pressure in line 38 exceeds the compression of spring 40, the flow of fluid through the valve being exhausted by the line 43 to the reservoir 5.

It is to be understood that the tonnage control valve just described may be replaced, for the purpose of reversing the motion of the platen, by a limit switch responsive to the position of the platen. The other valve which becomes operative at the time of press reversal is located within the reservoir 5, and is generally indicated at 44. Its purpose is to relieve the intense working pressure existing in the space above piston 2, and, while doing this, to by-pass to the reservoir the delivery of pump 6 into line 11 toward the push-back area of piston 2. This pressure-relieving and pump by-passing action provides a shockless reversal of the press. The valve 44 consists of the balanced plungers 45 and 46, both of which are urged toward the right under spring pressure. Normally, the spring pressure upon plunger 45 positions this plunger so as to block the port 47 opening into the reservoir, as well as one end of an internal passage 48. Likewise, the spring pressure upon plunger 46 normally positions it so as to block the port 49 opening into the reservoir.

During the working stage of the press, the plunger 46 shifts to the left, pressure within cylinder 3 being transmitted to it through lines 10, 37 and 50, overcoming the spring tension urging it to the right. When the working pressure reaches its predetermined limit and the tonnage control valve acts to reverse the delivery of pump 6, pressure within push-back line 11 is transmitted by lines 31 and 51 to the right end of plunger 45, shifting it to the left against its spring tension. Plungers 45 and 46 being thus shifted, port 47, passage 48, and port 49 are all uncovered, whereupon working pressure standing in line 37 is relieved through port 47 to the reservoir, and the delivery of pump 6 is by-passed through lines 11, 31 and 51, passage 48, and port 49 to the reservoir. Working pressure having been relieved, plunger 46 is spring-returned to its normal right-hand position, blocking port 49 and causing the delivery of pump 6 to be directed against the push-back area of piston 2. Also, since this pressure above the piston 2 is relieved, push-back pressure in line 33 is now enabled to open the surge valve, whereupon piston 2 proceeds to move upwardly to the starting position.

In order to prevent the development of dangerous pressures within the primary system, there are provided two safety valves 52 and 53. Valve 52 stands in the branch line 32, protecting the push-back side of the system, while valve 53 stands in the branch line 37, protecting the working side of the system. Both safety valves discharge into the reservoir.

There is also provided a check valve 54, its purpose being to permit fluid stored within the reservoir to be drawn into the line 31 and through it and line 11 to the pump 6, this passage of fluid taking place at certain times during the actual working stage of a pressing operation. Its action will be more fully described later in connection with a summary of the combined actions of all three hydraulic systems of this invention.

As stated above, the primary pressure system is operative at all times during a cycle of the press. From the description of this system it will be evident that this is the case; that the system is operative immediately upon the energization of the solenoid 12 to advance the platen toward the work, that it is operative during the working stage to drive the platen downwardly at high pressure and that it is operative, upon de-energization of the solenoid 12, to return the platen to its idling position and to maintain it in this position until the initiation of a new cycle. The primary pressure system is, indeed, solely operative to produce the first rapid work-approaching stroke of the press, and the entire return stroke. It is in the second, or working stage of the press that the primary pressure system is augmented by the auxiliary pressure system acting through the controls of the interconnecting system, and these systems will now be considered.

Auxiliary Pressure System

The auxiliary pressure system has its pressure source in a pump 55. This is a variable delivery high pressure pump, and may be of any well-known type. It is fitted with a pressure control which consists of a pressure cylinder 56 and a spring cylinder 57. The spring in cylinder 57 tends to hold the shift ring of the pump on full stroke, so that the pump will draw fluid from the reservoir 58 through the line 59 and deliver pressure through line 60. The pressure cylinder 56 is connected by the line 61 to a part of the pressure circuit in a manner later to be described, so that when pressure is built up in this part of the circuit to a point determined by the tension of the spring in cylinder 57, the pressure will overcome the spring tension and return the shift ring of the pump to neutral position, or nearly to neutral position. Under these conditions, the pump will deliver just sufficient volume to maintain pressure in the system as determined by the setting of the spring in cylinder 57. Two hand wheels, 62 and 63, are provided, one for adjusting the stroke of the pump, and one for adjusting the tension of the spring. The design and operation of this control is well known by those versed in the art.

A relief valve 64 is provided as a protection to prevent excessive pressures being built up in line 60 or in other parts of the auxiliary pressure system, in the event the pump control should fail from any cause. This relief valve exhausts through line 65 to reservoir 58. The shut-off valve 66 is provided in line 60 merely for the purpose of disconnecting the pump for repairs, without draining the system; it is fully opened when the system is in operation.

Pressure fluid from pump 55 is delivered through line 60 to an elastic pressure accumulator, generally designated 67. This accumulator

consists of a high pressure cylinder 68, having a bore 69 in which is fitted piston 70; and of an enlarged cylinder 71 having a bore 72 in which is fitted piston 73. The two pistons, 70 and 73, are rigidly interconnected by the rod 74. In the drawings the cylinder 71 is shown broken above piston 73, to indicate that the height of this portion of the cylinder is dependent upon the particular pressure drop to be allowed between the uppermost and lowermost positions of the piston. For instance, if a 20 per cent drop is decided upon, the total height of the cylinder will be five times the stroke of the piston.

The space above piston 73 is filled with an elastic fluid medium, as for example with air, or some inert gas such as nitrogen, helium or neon. It will be readily recognized that as fluid pressure is pumped into the bore 69 of the accumulator 67, piston 70, rod 74 and piston 73 will be pushed upwardly to compress the elastic medium in bore 72 above piston 73.

Attached to piston 70, as by rod 75, is a cam 76 which is located outside the accumulator 67 and is adapted to actuate the control valve 77, this valve being located in the line 61 and being designed to control the stroke of pump 55. Valve 77 contains a piston 78 on the right end of which is mounted a ball, or roller, for contacting cam 76. Piston 78 is forced to its extreme right-hand position by a spring 79, this position of the piston being seen in Figures 3 and 4. While in this position, the piston shuts off passage of fluid from the line 80 to the line 61, the line 86 being a branch of line 81 leading to the fluid pressure bore 69 of the accumulator 67. At the same time, line 61, which is connected to the pressure cylinder 56, is in communication with line 82, in turn connected to exhaust line 83, which leads to the reservoir 58. Under this condition, no pressure can exist in cylinder 56, and pump 55 will be held on full stroke position by the spring in cylinder 57, so that the full delivery of the pump is directed into the accumulator 67, storing pressure fluid in the bore 69.

In Figure 4, the accumulator is shown nearly filled, with the piston 78 of valve 77 standing in its extreme right-hand position. A slight additional upward movement of the accumulator piston, which position is illustrated in Figure 1, will bring cam 76 into contact with a roller on the end of piston 78, forcing this piston to the left against the pressure of spring 79. This action of the piston will close connection between lines 61 and 82, and will open the connection between lines 61 and 80 allowing pressure from accumulator 67 to act in the pressure cylinder 56 of pump 55.

This pressure will overcome the setting of the spring in pump cylinder 57 and will shift the ring of the pump toward the left, or to neutral. Under this condition, the pump will deliver just sufficient fluid into the accumulator 67 to maintain it fully charged.

The provision of the valve 77 in the auxiliary pressure circuit insures that whenever the accumulator is not fully charged, the pump 55 will supply pressure fluid to the accumulator 67 at its maximum output capacity. As indicated above, valve 77 is not actuated by cam 76, and the control 56 of the pump is not, therefore, subjected to pressures within the accumulator 67, until cam 76 has been carried by pistons 70 and 73 almost to the upper limit of its travel, where the elastic medium above piston 73 has been compressed to the desired point, and the bore 69 has been completely filled with working fluid. Thus, although the pump 55 is shifted to its no-delivery, or neutral position, in response to fluid pressure within the bore 69, it is subjected to that pressure through the valve 77 only when the positions of pistons 70 and 73 indicate that the pump has fully performed its charging function. It will be noted that because of this provision, pump 55 will always be delivering at its maximum rate during a downstroke of piston 70, thus supplementing the stored volume of accumulator fluid in producing the high speed stroke of the press at high pressure.

For replenishing any of the gaseous medium that may be lost from the accumulator, there is provided a supply line 71*a*, in which is placed a shut-off valve 71*b*. Normally the valve 71*b* is closed, the accumulator requiring no operating connection to its source of gas supply. When the addition of gas to the accumulator is found necessary, valve 71*b* is opened to permit a flow from the gas source to the accumulator. The pressure of the gas supply will be equal to the minimum gas pressure within the accumulator, that is, the pressure when piston 73 is at the bottom of its stroke.

The cylinder 71 is also provided, at its lower end, with a breather line 71*c*, the purpose of this line being to maintain atmospheric pressure on the underside of piston 73.

There is provided in the upper end of cylinder 68 a port 84 by which the drain line 83 is connected to the bore 69 above the piston head 70. This arrangement provides for conducting back to the reservoir 58 any fluid which leaks past the piston head 70 from the lower, high pressure end of the bore 69.

The reservoir 58 is joined with the reservoir 5 of the primary pressure system by the pipe line 85. Pressure fluid transferred from the accumulator to the press is ultimately returned to the reservoir 58 from which it originally was taken, by being expelled into the reservoir 5 upon the retraction stroke of the press, and then overflowing into the line 85.

Interconnecting Control System

The purpose of the system now to be described is to release, during the working stage of the press cycle, the kinetic energy of the gaseous medium compressed above piston 73 of the accumulator, and to expend this energy upon the work by conducting to the working area of piston 2 the fluid contained within the bore 69 of the accumulator.

The passage of fluid from the accumulator is through line 81 and valve 86 into line 87. The valve 86 is simply a service valve similar to the valve 66, and is normally fully open. Line 87 leads to a metering valve 88, pressure fluid being discharged from this valve through a choke valve 89 and thence, through line 90, to a pilot operated two-way valve 91. A line 92 leading from this two-way valve joins the main pressure line 10, and it is by opening a passage into this line 92 from line 90 that the two-way valve 91 opens a passage from the accumulator 67 to the press.

The open or closed position of valve 91 is determined by pilot pressure in the lines 93 and 94. This pilot pressure is taken from the pressure line 87 through branch line 95, choke valve 96, and line 97 to the four-way pilot valve 98. Depending upon the setting of this pilot valve, fluid is conducted from line 97 into either pilot line 93 or 94, for controlling the position of the

two-way valve 91. The setting of valve 98 is determined by the energization or de-energization of a solenoid 99, and by the compression of a spring 100 opposing the solenoid. When energized, the solenoid 99 actuates the piston 101 of the valve 98 so as to connect lines 97 and 94, exhausting line 93 to the drain line 83. At this time, the compression of spring 100 is exceeded by the pull of the solenoid core. When, however, the solenoid 99 is de-energized, the spring 100 actuates the valve piston 101 so as to connect lines 97 and 93, exhausting line 94 to the drain line 83.

The solenoid is shown in its de-energized state in Figures 1, 2, 3 and 4. From these views of the drawings and from the foregoing description, it will be apparent that energization of the solenoid 99 results in the opening of the two-way valve 91, and that de-energization of the solenoid results in the closing of this valve, by directing pressure into pilot lines 94 and 93 respectively. The choke valve 96 standing in the inlet line 97 of the pilot valve 98, regulates the fluid velocity into the pilot lines 93 and 94, and consequently, the speed of opening or closing of the two-way valve 91.

The purpose of the metering valve 88 and the choke valve 89 is to regulate the transfer of fluid from the accumulator to the press, once that flow has been started by the energization of solenoid 99 and the consequent opening of valve 91. The setting of the choke valve 89 is responsible for the general rate at which the transfer of fluid takes place, while the metering valve 88, in cooperation with the choke valve 89, serves to maintain that rate constant against varying resistances offered by the work, and also, at the moment of opening of valve 91, serves to cushion the impact of accumulator pressure upon the press.

Valves 88 and 89 may be regarded as two chokes in the pressure line between the accumulator and the press. Valve 89, after being manually adjusted, is a fixed choke, while valve 88 is a variable choke, its restriction of the pressure line increasing and decreasing inversely with pressures in line 90.

Briefly, the metering valve consists of a plunger 102 urged in one direction by a spring 103. The plunger 102 is provided with metering flutes or grooves 104, these flutes permitting more or less passage of fluid from the line 87 to the choke valve 89, as plunger 102 is raised and lowered, respectively. The pressure on the inlet side of the choke valve 89 is communicated to the end of the plunger 102 opposite the spring 103 by the line 105. The pressure on the outlet side of the choke valve 89, that is, the pressure identical with that exerted upon press piston 2, is communicated to the spring loaded end of the plunger 102 by the line 106.

During the idling stage of the press, when no flow of pressure fluid is taking place through valves 88 and 89, pressures in the control lines 105 and 106 are identical and spring 103 holds the plunger 102 in its uppermost position, where the flutes 104 present the least possible restriction to fluid flow. This position of the metering valve is seen in Figure 1. At the instant that two-way valve 91 is opened to discharge the accumulator, the pressure in line 90 on the outlet side of choke 89 will momentarily drop, and this change will be communicated to the metering valve through line 106. The effect of this sudden drop of pressure bearing upwardly against the plunger 102 will be to permit this plunger to move downwardly, pressure in line 105 still being relatively high. Because of this downward motion, the restriction through the flutes 104 is greatly increased, with the result that the tendency of accumulator pressure fluid to rush into the pressing area of cylinder 3 is checked. Gradually, as pressure rises in line 90, the restriction at valve 88 decreases and the rate of flow to the press increases. The metering valve thus releases accumulator pressure without shock upon the press.

During the pressing operation, varying work resistances will be registered upon the metering valve plunger 102 through the line 106. Lowered pressures in this line will permit the valve plunger to move downwardly under the influence of the pressure in line 105, this movement resulting in a greater restriction of the fluid passage along the flutes 104, thereby reducing the flow from line 87 to the choke 89. Increased pressures, on the contrary, cause the valve plunger to move upwardly, so that larger areas of the flutes 104 are exposed to the fluid passage, and the flow to valve 89 is increased. The press movement is thus maintained at a constant rate, namely, the rate predetermined by the manual adjustment of choke 89.

Energization of the solenoid 99, to initiate the transfer of pressure fluid from the accumulator to the press, takes place just before the platen 4 engages the work. To provide for this accurately timed energization, there is attached to the platen a control rod 107 having the cam face 108, this cam face being adapted to engage and close a normally open limit switch 109. The position of this limit switch is adjusted to meet the requirements of different pressing operations.

Operation of Combined Systems

Idling

In describing a complete cycle of operations of the press, attention is directed to Figures 1 to 4 of the drawings. In Figure 1, the press is seen in its idling state, the platen 4 being fully withdrawn from the work, and dwelling in this condition, although in readiness for a pressing stroke. No appreciable flow of pressure fluid is taking place in the primary system, the pump 6 being held in its neutral, no-delivery position by the upward force of the collar 25 of the control rod 13 acting upon one end of the lever 14. Such flow as does occur is toward the push-back area of piston 2, and is due to leakage of pressure fluid from this area, with the consequent lowering of the platen and actuation of the pump through collar 25, to delivery into line 11 an amount of fluid sufficient to compensate for the leakage.

As to the auxiliary pressure system, the pump 55 has moved the pistons 70 and 73 of accumulator 67 to their fully charged positions, and has itself been shifted to neutral position in response to pressure within bore 69. It is, at this time, operative only to restore the accumulator to its maximum pressure state as fluid within the bore 69 is lost through leakage.

The accumulator is maintained in its passive condition by the blocking of its pressure fluid in the interconnecting system, specifically at the valve 91, which is closed. This valve is forcibly maintained in its closed position by the action of static fluid pressure from the accumulator, transmitted through valves 96 and 98, and pilot line 93.

Rapid traverse toward work

When it is desired to start a pressing operation the operator closes the energizing circuit for the pump solenoid 12. The pump 6 is immediately actuated to deliver at its maximum rate into lines 9 and 10 toward the pressing side of piston 2. Its entire fluid supply is taken fom the push-back side of this piston through line 11. This piston, with plunger 1 and platen 4, drop of their own combined weights as rapidly as withdrawal of push-back fluid takes place. Since the volume of this fluid is much less than that required to fill the space above the piston 2, a suction is created in this space by the descending piston sufficient to draw piston 27 of the surge valve 26 down against the spring 28, opening the passage to reservoir 5, and permitting a surge of storage fluid into the pressing space.

Figure 2 of the drawings illustrates the condition just described, solenoid 12 being shown collapsed, arrows indicating the direction of flow of fluid, the platen shown descending, and the surge valve shown diagrammatically in its opened position. No change in the condition of the auxiliary and interconnecting systems has occurred, the solenoid 99 not yet having been energized. Only the primary system is operative at this stage.

Working stroke

The distance from its idling position to the work piece having been traversed, the platen 4, through the rod 107 and cam 108, actuates the limit switch 109, which controls the energizing circuit for the solenoid 99, and closes this switch, thereby energizing the solenoid 99. By this action, the platen of the press causes the interconnecting control system to release the stored energy of the auxiliary pressure system, directing it to the pressing side of piston 2. Figure 3 of the drawings shows the press and the system controls in the positions they assume immediately after this release of accumulated energy takes place. The flow of pressure fluid is indicated by bold arrows, while the flow of pilot fluid is indicated by light arrows.

In the primary system, no significant change has occurred except that the surge valve has been closed by the development of pressure in the space above piston 2. The pump, however, continues to withdraw from the push-back side of the piston 2, and to supply fluid, now under high pressure, to the main working area of the piston.

Upon energization of solenoid 99, plunger 101 of pilot valve 98 is moved so as to expel the fluid from line 93 into line 83, while pilot pressure is conveyed into line 94. The two-way valve 91 is thus moved to its upper or open position and the flow of pressure fluid from line 90 to lines 92 and 10 immediately ensues. The rate at which this flow takes place is governed by the opening of the choke valve 89, and when this valve is appropriately adjusted by the operator, this rate will be such as to cause the pressing piston 2 to move into the work without a reduction of its previous rapid traverse speed. That is, the large volume of pressure fluid supplied by the accumulator, added to the smaller volume supplied by pump 6 will equal the previous sum of the make-up volume from the reservoir 5 and the output of pump 6.

If the operator has opened choke valve 89 too much so that too great a volume of pressure fluid is delivered from the accumulator into the press cylinder, the press speed may tend to increase. In this event, pressure would be built up on the push-back side of the press. This pressure will act through line 11 and branch lines 31 and 51 into the valve 44, which valve will thus be opened to relieve excess pressure fluid in the press cylinder, just as at the time of press reversal. The action of valve 44 in this connection determines the maximum speed of pressing.

If the operator has opened valve 89 only partially, the working stroke of piston 2 will proceed at a rate slower than the work-approaching rate, and some fluid will be drawn from the reservoir 5 through check valve 54 by the pump 6. The amount of fluid so drawn from the reservoir will be that required by pump 6 in excess of that available in the push-back portion of cylinder 3.

The impact of accumulator pressure upon the press is cushioned, in the manner described in detail above, by the metering valve 88. As the working stroke of the press is executed, and varying resistances are offered by the work, the flow of fluid through valve 89 will be kept at a constant rate by the self-adjustment of metering valve 88 in response to these variations.

Initiation of reversal

The working stroke of the press continues at high speed and high pressure until the pressure setting of the tonnage control valve 36 is reached. The actuation of this valve is the first event in the initiation of the return of the press platen, its opening, and the actuation of other controls immediately thereafter being illustrated by Figure 3.

In this figure the press platen has progressed downwardly to its limit for the particular work piece in the press, as likewise the moving element of the accumulator. Back pressure in line 38 to tonnage control valve 36 has collapsed the spring within this valve, moving cam 41 into position to open limit switch 42. As explained above, opening of this switch breaks the circuit to all electrical controls, and, consequently, solenoids 12 and 99 are now in their extended positions.

Solenoid 12, upon de-energization, has permitted the spring within the control 7 of pump 6 to shift the pump to its full delivery position in the direction of the push-back area of piston 2. This piston is, at the moment, locked against movement by the extreme pressure on its upper surface, and the discharge of pump 6 is conducted through branches 31 and 51 to the by-pass and relief valve 44. The plunger 45 of this valve yields to the left under the pressure in line 51, and the output of pump 6 is then by-passed through passage 48 and port 49 to the reservoir, the port 49 already being opened by the movement of plunger 46 to the left under the influence of working back-pressure in line 50. As soon as the movement of plunger 45 uncovers port 47, this back pressure is relieved, passage of fluid being from lines 10 to 37, and through port 47 to the reservoir. This action of valve 44 is only momentary, and serves to eliminate shock in the press due to its reversal of direction.

De-energization of solenoid 99 immediately results in cutting off the transfer of pressure fluid from the accumulator to the press, this action proceeding from the upward shifting of plunger 101 of pilot valve 98, and the reversal of pilot pressure in the lines 93 and 94 to close the valve 91.

The pump 55 is, of course, delivering at its full rate into the line 60, having been put on stroke shortly after the engagement of the work by the press, and the opening of control line 61 through valve 77 to the reservoir by the downward motion of cam 76. As this cam has moved to a still lower position than in Figure 3, the line 61 is still connected to the reservoir through valve 77.

Return stroke

Figure 4 shows the return stroke of the press, and the simultaneous re-charging stroke of the accumulator. This view is representative of the entire press return movement, no change in the setting of the controls taking place until the idling position is reached.

The platen is returned solely by the delivery of pump 6 toward the push-back side of piston 2. Part of the fluid above this piston is drawn upon by the pump through lines 9 and 10, the remainder being exhausted through the surge valve 26 to the reservoir 5, from which the proper proportion is carried by the pipe line 85 to the reservoir 58. The surge valve is forcibly held open by the push-back pressure communicated to it through branches 31 and 33 of line 11. The action of the surge valve in this stage of the press cycle aids in producing a rapid motion of the platen, just as in the work-approaching stage. In both stages, it serves to make up the difference in the volumetric requirements of the cylinder 3 above and below the piston 2, the speed of the piston being determined by the full capacity of pump 6 in delivering to, or drawing from the relatively small push-back area.

The valve 91 of the interconnecting controls having closed at the point of press reversal, it remains closed even though limit switch 109 is contacted by cam 108 during the press return movement.

In the stage illustrated by Figure 4, the accumulator is being charged at the full delivery rate of pump 55, the valve 77 preventing fluid pressure within bore 69 from being communicated to the pump control 56, until the cam 76 shifts the valve, indicating complete charging of the accumulator.

Representative pressures

The press as described lends itself to a wide range of pressures, of which the following are to be considered merely representative.

Pressure upon the piston 2 may be at about 1250 pounds per square inch during the working stage. Pump 6 and accumulator 67 will then be designed to deliver pressures somewhat in excess of the amount, to compensate for frictional losses in the working parts, the pipe lines and the control valves. It might, for example, be estimated that such losses between the accumulator and the main piston would total 100 pounds, in which case the minimum pressure available within the accumulator would be 1350 pounds per square inch.

This is the pressure that would be exerted by the gaseous medium on the pressure fluid of the accumulator at the limit of the downward stroke of the accumulator pistons, or, in other words, when the gas had reached its maximum allowable expansion. When the accumulator is fully charged and standing in its uppermost position, this pressure will, of course, be higher, a typical increase being about 20 per cent. In the present instance, this would give a maximum accumulator pressure of 1620 pounds per square inch.

Again allowing for frictional losses in the accumulator and the circuit, the pump 55 would be designed for pressures greater than this maximum. A loss of 100 pounds of pressure, for example, would require that this pump have a peak delivery of at least 1750 pounds per square inch.

It may be repeated here that the work-approaching stroke of the main piston is accomplished at little or no pressure, this stroke being produced by the lowering of this piston, along with plunger 1 and platen 4, under the influence of gravity, at the relatively high rate of removal of fluid from the push-back area of the piston.

Summary of main features

The press platen of this invention is moved to and from the work at high speed by the pump of a primary pressure system, this pump also being operative to assist in effecting the high pressure stroke.

There is provided an accumulator for adding pressure fluid to that supplied by the pump of the primary system, so as to produce a press working stroke of high speed as well as high pressure. This accumulator is part of an auxiliary pressure system, having a separate pump and being charged by this pump at full delivery in all except its fully charged position. The pump stores hydraulic fluid in the accumulator, and at the same time compresses a gas therein. At the appropriate time in a pressing cycle, the pressure of this gas, reacting upon the body of hydraulic fluid, forces this fluid through an interconnecting system to the press.

The release of accumulator pressure fluid is timed by the position of the press platen acting through electrical control means to open a valve in the interconnecting system. This occurs just prior to the closing of the press upon the work.

The tendency of accumulator pressure to be released with shocking force upon the press is checked by a metering valve, responsive to pressures at the inlet and outlet of a choke valve, the latter being the manual control of the transfer rate of accumulator fluid. As the working stroke proceeds, and varying resistances are met, the metering valve functions to prevent fluctuations in this rate.

When properly positioned, the choke valve in the fluid transfer line makes possible a pressing speed as high as the initial approaching speed of the press. This high speed is effective throughout as long a working stroke as the fluid storage capacity of the accumulator is designed to produce.

An electrical circuit is provided, in which originates the control impulses for starting the press, releasing accumulator energy, and reversing the press movement. The second of these steps is made dependent upon the first, so that it can not occur during the return stroke.

Reversal of the press is accomplished either in response to the pressure or position attained by the press. Shock due to reversal is eliminated by a valve which momentarily opens to relieve the high working pressure above the press piston, and to by-pass the pump which at that moment has been actuated to deliver toward the push-back side of the piston.

An important advantage of the invention is that the bulk of the accumulator is kept at a minimum. This is accomplished by employing the accumulator fluid only during the high pressure stage of the cycle, by adding the total output of both pumps to the accumulator output at this

stage, and by charging the accumulator, if necessary, at the full rate of delivery of one pump, whenever the other pump is causing the press platen to advance toward the work, to retract from the work, or to stand in its idling position. The accumulator is made as compact as possible, in other words, by designing it to store only as much pressure fluid as is needed to produce, together with the two pumps, a high speed, high pressure stroke of the press. The output of one of the pumps produces all other motions of the press, while the output of the other pump simultaneously charges the accumulator.

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 combination in a hydraulic system, a pump, fluid operable means for moving said pump from full stroke to neutral position, an accumulator adapted to be charged with fluid from said pump, valve means normally preventing fluid connection between said fluid operable means and said accumulator, and means responsive to the completion of the charging of said accumulator for causing said valve means to establish fluid connection between said fluid operable means and said accumulator thereby causing said pump to move to neutral position.

2. The combination in a hydraulic system of a pump, fluid operable means including a pressure chamber for moving said pump from full stroke to neutral position, an accumulator adapted to be charged with fluid from said pump, valve means including a valve member normally preventing fluid communication between said pressure chamber and said accumulator, and means movably connected with said accumulator, and adapted in response to a predetermined position of the latter to establish said fluid communication to thereby cause said pump to move to said neutral position.

3. The combination in a hydraulic system of a variable delivery pump, fluid operable means operable to move said pump from full stroke to substantially neutral or no-delivery position, an accumulator adapted to be charged with fluid from said pump, valve means interposed between said fluid operable means and said accumulator for controlling fluid communication therebetween, said valve means including a reciprocable member and yielding means normally holding said member in position for preventing said fluid communication, and means on said accumulator and adapted in response to a predetermined position thereof to move said member against the thrust of said yielding means into position for establishing said fluid communication, to thereby cause said pump to stop charging said accumulator.

4. In combination in a hydraulic system, a variable delivery pump, fluid operable means operable to move said pump from full stroke to substantially neutral or no-delivery position, an accumulator adapted to be charged with fluid from said pump, said accumulator including a cylinder with a fluid operable plunger reciprocably mounted therein, control valve means including a valve member normally preventing fluid connection between said fluid operable means and said cylinder, and means operable by said plunger and adapted in response to a predetermined position of the latter to move said valve member into position for establishing said fluid connection, to thereby bring about a return of said pump to neutral position.

5. In combination in a hydraulic system, a pump, means including a pressure chamber for moving said pump from full stroke to neutral, an accumulator containing a piston which is actuated by pressure fluid derived from said pump, said fluid being admitted to said accumulator only on one side of the piston, a fixed gas in said accumulator on the other side of the piston, a control valve interposed between the accumulator and the pump for controlling the flow of pressure fluid to the accumulator, and means including a cam secured to said piston for closing and opening said valve whereby when the valve is opened fluid pressure is admitted to one end of said accumulator to compress the gas at the other end of the accumulator.

6. In combination in a hydraulic system, a fluid pressure pump, means including a pressure chamber for moving said pump from full stroke to neutral, and an accumulator of fluid energy, said accumulator comprising a closed cylinder containing a double-headed piston, the space between one side of said piston and the adjacent end of said cylinder being in communication with the pump for the purpose of actuating said piston, the space between the other side of said piston and the adjacent end of said cylinder being filled with a compressible gas so that as pressure fluid is admitted into the cylinder from said pump said gas is compressed and the energy of the compressed gas is available to force the pressure fluid at the opposite side of the piston into the hydraulic system, the end of the cylinder to which the pump is connected being in communication with said pressure chamber of the pump through a control valve, said valve being controlled by the movement of the piston in said accumulator during the compressing action of the compressible gas to effect a return of the pump to neutral when the compressing operation of the gas has been completed and the accumulator is full of fluid energy derived from the pump.

WALTER ERNST.