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L. A. CAMEROTA

2,473,676

CONTROL SYSTEM FOR HYDRAULIC MACHINERY

Filed March 9, 1946

6 Sheets-Sheet 1

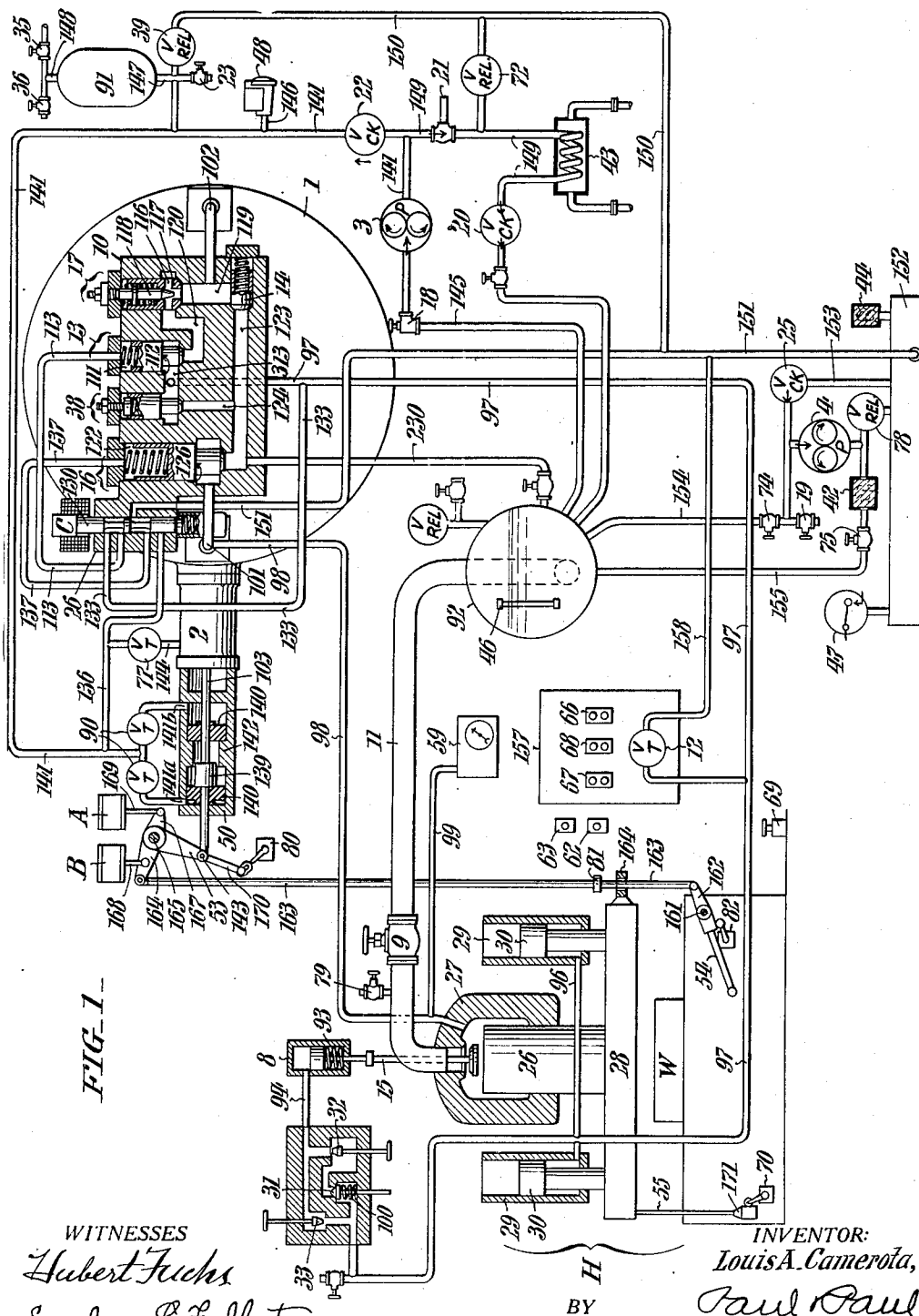


FIG. 1

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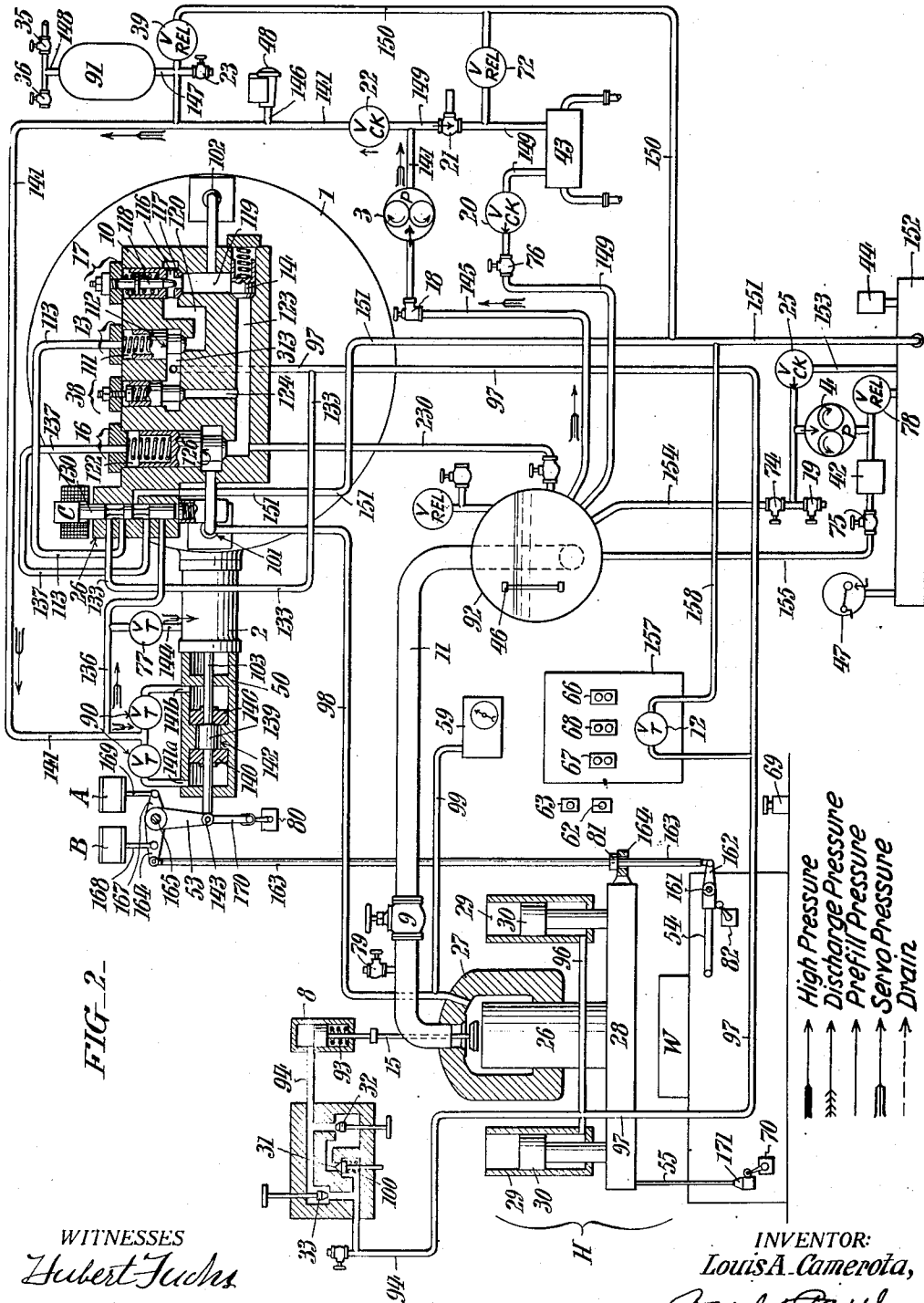
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6 Sheets-Sheet 2



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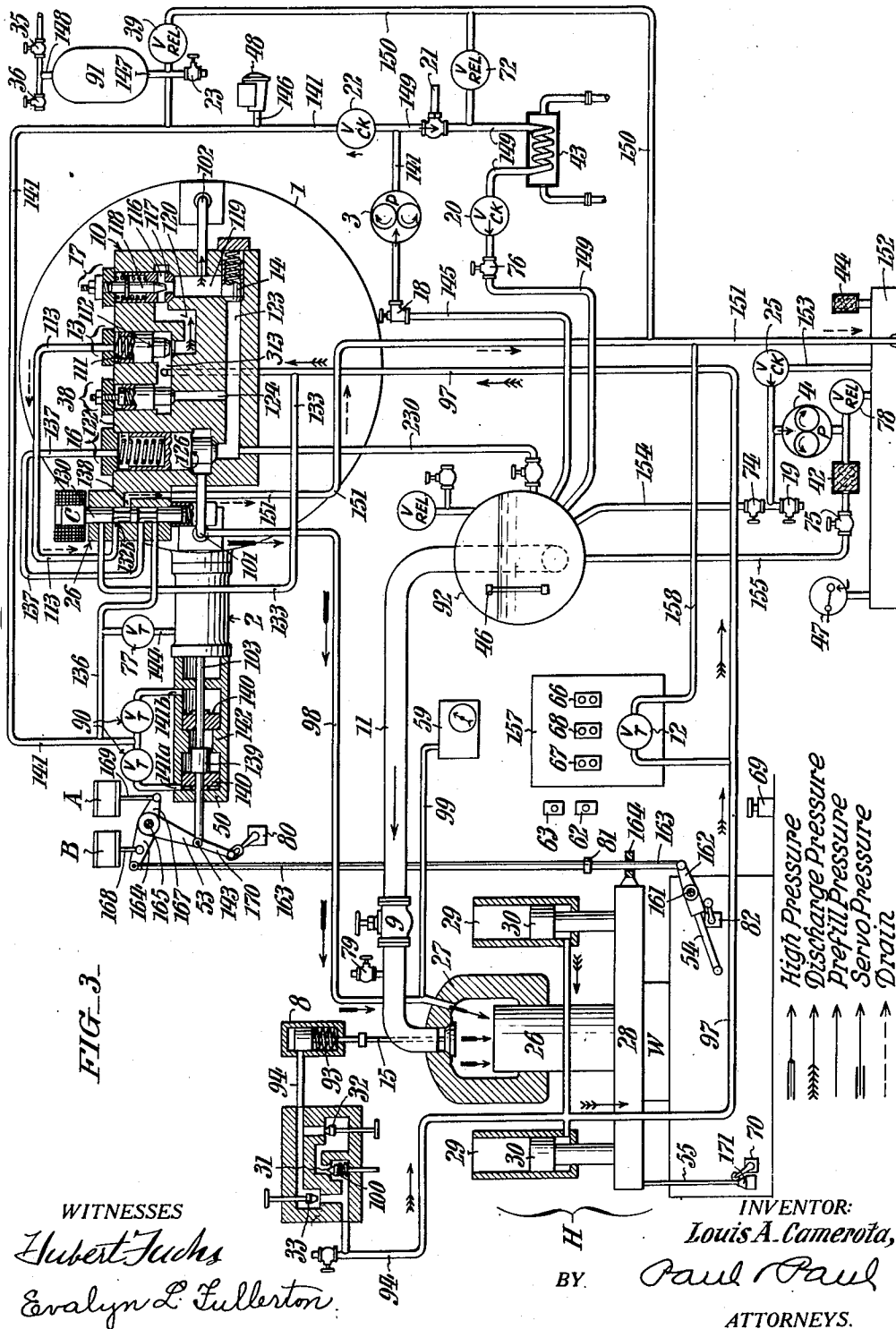
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CONTROL SYSTEM FOR HYDRAULIC MACHINERY

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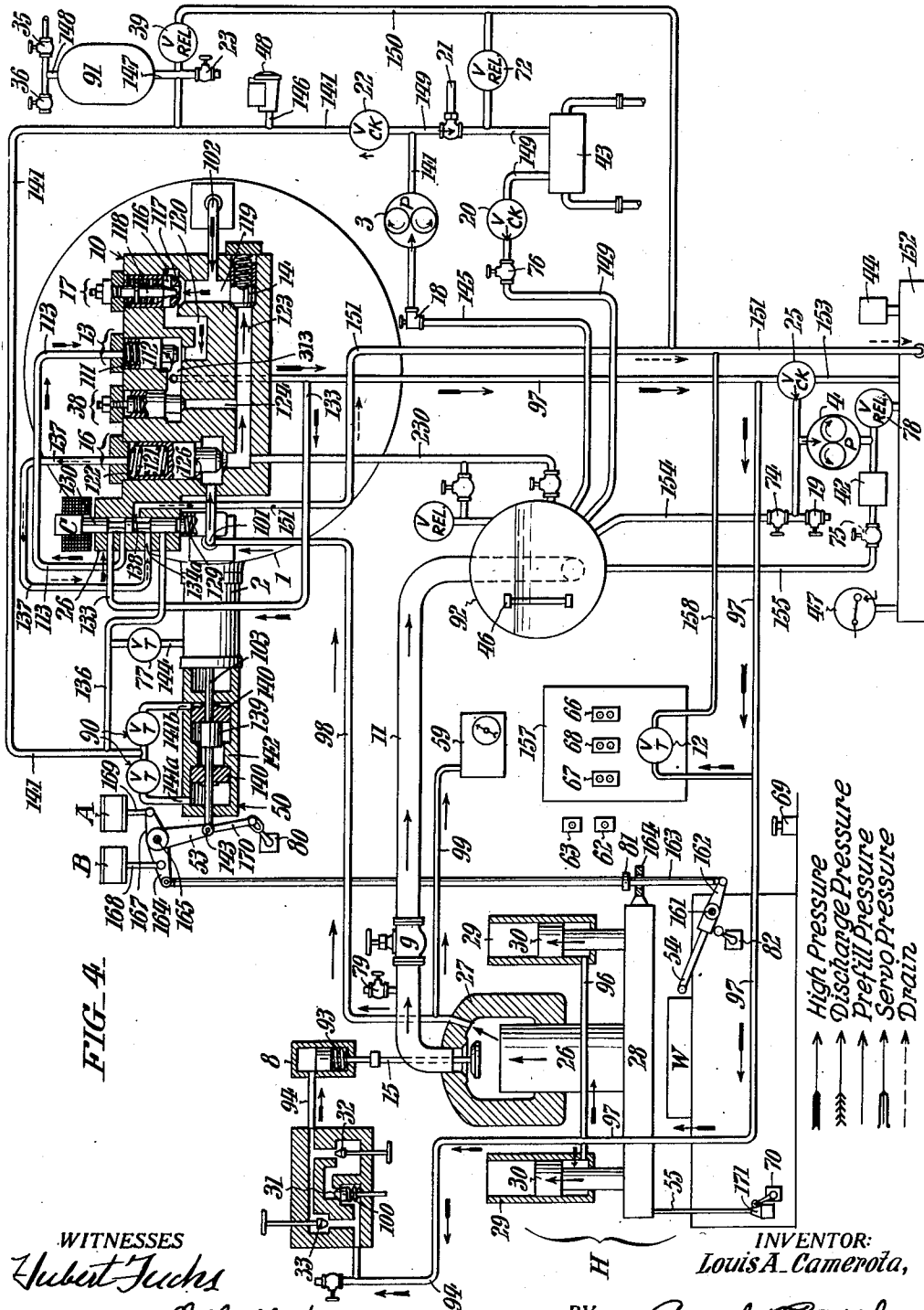
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6 Sheets-Sheet 4



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CONTROL SYSTEM FOR HYDRAULIC MACHINERY

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9 Claims. (Cl. 60—52)

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This invention relates to a control system for hydraulic machinery and more particularly for use with hydraulic presses or the like operated through the medium of a pump having a flow control member which is adapted to be shifted to different positions by means of a servo-motor. Presses operated by such instrumentalities are well known in the art, and my invention is directed to improvements which provide a more versatile control for a hydraulic press or the like, which safeguard against improper operation or excessive loads upon the power transmission lines, and which involve advantages as more fully set forth in this specification.

The use of the rotary piston type pump, combining variable volume and variable pressure, and of the servo-motor for shifting the rotor or flow control member of such a pump to effect volume and directional control, as well as other well known improvements relating to presses or other hydraulic machinery, and to apparatus for controlling their operation, has made possible the design of very large hydraulically operated units which are capable of exerting a great force in a limited space. This has resulted in a tendency favoring high speed and high capacity press units requiring a large pump with consequent increase in the horse-power of the prime mover which drives the pump, especially at peak loads.

It follows that where an electric motor is employed as the main prime mover of the system, in starting a motor of the size required, particularly if it is attempted to start the motor while the pump driven thereby is on stroke or under pressure, a tremendous demand is created upon the power lines. Even under conditions where the pump is in the neutral or no-delivery position the starting of the motor may require more current than the lines normally installed in a factory or mill can safely conduct. On account of its particular characteristics, the use of a synchronous motor has been suggested, it being well known that very little current is required to start a synchronous motor as compared with other types. But although synchronous motors have a better power factor they cannot be used to advantage except where the starting torque required is small, or the load can be relieved during the starting period. Furthermore, in a plant where a large hydraulic press of the type referred to herein is operated by an electric motor other than a synchronous motor, and adequate transmission lines are installed, for meeting the peak loads, the starting of the motor under load will cause

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heavy demands which should, if possible, be avoided.

With these considerations in mind it is one of the principal objects of my invention to provide in such a hydraulic system means for preventing the electric motor used as the prime mover from being started when the pump is on stroke or in a position to deliver pressure to the hydraulically operated machine. This is accomplished by control devices which make it a condition precedent to the starting of the motor that the flow control member of the pump be shifted to the neutral or no-delivery position so that the motor is always permitted to start with only its own frictional load and that of the pump to overcome.

A further object of the invention is to provide in such a system a full set of controls, whereby the various functions of a press or the like may be performed automatically in the desired sequence, or at the will of the operator, and preferably including a manually operated control, which, if the electrical appliances fail, or under any emergency or unusual condition, can be relied upon to predominate over other controls and move the press platen as desired.

A further object of the invention is to reduce to a minimum the number of valves and the amount of exterior piping associated with the press by combining the functions of such valves, to a greater extent than has heretofore been accomplished, and by placing them in juxtaposed relation within a unitary structure desirably mounted integrally with the pump, or in close relation thereto.

Further objects of my invention and advantages which result from the use thereof will become more apparent from the description of a preferred embodiment of the invention which follows hereinafter and which has reference to the accompanying drawings wherein:

Fig. 1 shows a diagrammatic layout of the hydraulic elements of the control system with the press idle and its platen at the upper limit of travel, and with none of the pumps operating.

Fig. 2 shows the same layout with the press idle but with the servo-motor pump operating.

Fig. 3 shows the same layout with the press platen closed against the work piece.

Fig. 4 shows the same layout with the press platen moving up.

Fig. 5 shows a diagram of the electrical circuit for operating the main motor which drives the main pump.

Fig. 6 shows a diagram of the electrical circuit

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for operating the controlling relays of the hydraulic control system.

Fig. 7 shows a diagram of the electrical circuit for operating the motor which drives the pump of the leakage system.

Fig. 8 shows a diagram of the electrical circuit for operating the motor which drives the pump of the servo-motor system; and

Fig. 9 shows an enlarged cross-sectional view of the combined valves which control the flow of hydraulic fluid between the press and the main pump.

General description

In the drawings, with special reference to Figs. 1 to 4, a hydraulic press is comprehensively designated at H. Pressure fluid is supplied to the press H through the medium of a reversible variable delivery pump 1 controlled by a servo-motor 2. It may be assumed that the pump includes a rotor or flow control member (not shown) which is adapted to occupy different positions including a neutral or no-delivery position and on-stroke positions in which pressure or suction is applied to the connecting lines depending upon which side of the center line the rotor of the pump is moved. The details of construction of the pump 1 and servo-motor 2 and means for varying the output of the pump 1 are not shown in the drawings of this application as they do not form any part of my invention and such devices are well known and have long been used with hydraulic presses.

In addition to the main pump 1 the system includes a hydraulic gear pump 3 operated at, say, one hundred pounds working pressure and used to supply fluid power to the servo-motor 2 and an additional hydraulic gear pump 4 operated at, say, sixty pounds working pressure and used for the leakage system.

A synchronous motor, shown at 5 in Fig. 5, serves as the prime mover for driving the main pump 1. Additional electric motors employed in the system comprise a small induction motor 6, shown only in Fig. 8, which drives the hydraulic gear pump 3 for the servo-motor 2, and a motor 7, shown only in Fig. 7, which drives the hydraulic gear pump 4 of the leakage system.

The hydraulic press H conventionally illustrated includes a ram 26 reciprocating in a main cylinder 27 and connected at its lower end to a platen 28. For retracting the platen 28 push back cylinders 29 are used, these cylinders having reciprocating plungers 30 therein which are also connected to the platen 28. A pre-fill tank or reservoir 32 supplies fluid at a pressure of, say, thirty-five to forty pounds per square inch through a pipe 11 to the top of the main cylinder 27, there being a gate valve 9 in the pipe 11 for regulating the flow of the pressure fluid to the press cylinder 27, and an air cock 79 in the pipe 11 between the gate valve 9 and the cylinder 27. A sight gage 46 on the exterior of the pre-fill tank 32 indicates the level of the liquid therein. Associated with the press cylinder 27 there is a filling check valve 8 which controls admission of the pressure fluid from the pipe 11 to the top of the cylinder. The spindle 15 of the filling check valve 8 is normally held closed by means of a spring 93 but when pressure in the line 94 is sufficient to overcome the force of the spring 93 the valve spindle 15 is moved downwardly to open the valve 8 and permit fluid in the pipe 11 to enter the top of the cylinder 27. Three valves 31, 32 and 33 in the line 94 govern the operation of the filling check valve 8. More specifically, the check valve 31, which opens against the pressure

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of a spring 100, controls the closing speed of the filling check valve 8; the throttle valve 32 controls the amount of flow out of the filling check valve 8 through check valve 31; and the throttle valve 33 prevents a sudden application of high pressure to the filling check valve 8, and hence controls the speed of opening of that valve. The push back cylinders 29 are cross connected by a pipe 96 which joins the pipe 97. Pressure fluid from the main pump 1 at pressures which may be assumed to vary from zero to, say, three thousand pounds per square inch is fed to the push back cylinders 29 through a pipe 97 which joins pipes 94 and 96. Similarly pressure fluid having the same range of pressure is admitted to the main cylinder 27 of the press H through a pipe 98 leading from the pump 1. Joining the pipe 98 in the vicinity of the press is an additional pipe 99 which leads to a pressure governor 59.

The suction and discharge points of the main pump 1 are illustrated at 101 and 102. The pump 1 being reversible the connection at 101 is a point of discharge when the press is moving down and the connection at 102 is a point of discharge when the press is moving up. It may further be assumed that the reciprocable element 103 which controls the servo-motor 2, when shifted to the left, as viewed in Figs. 1 and 3 of the drawings herein causes a shift in the flow control member of the pump such that the pump 1 is on stroke, discharging at connection 101 through pipe 98 and taking suction at connection 102, and that when the reciprocable element 103 is shifted to the right the flow control member moves to a position such that the pump 1 is on stroke in the opposite direction discharging at connection 102 through pipe 97 and taking suction at point 101. Moreover, when the reciprocable element 103 occupies a central position the flow control member of the pump 1 is in the neutral or no-delivery position.

Mounted on the main pump 1 and shown in enlarged detail in Fig. 9 is a combination or manifold valve which includes within the same unitary structure 10 a series of serially arranged juxtaposed valves performing various functions. The valve 13 is a check valve having a spring 110 urging it to closed position and having an upper chamber 111 into which pressure fluid may be admitted to supplement the force of the spring in urging the valve 13 to closed position. An annular shoulder 112 at the base of the valve 13 is so proportioned that when the pressure in the passage 313 reaches a certain point the valve will open. Between the discharge or suction connection 102 and the check valve 13 there is interposed a throttle and check valve 17 which is urged to seated position by means of a spring 115 and which has orifices 116 in the valve part 117 which permit a limited flow through the valve part 117 when it is seated under spring pressure. For controlling the amount of flow through the orifices 116 an adjustable throttle rod 118 is employed, its position being determined by means of a nut 114 engaging the threads 250 and by means of a spring 251 which presses against a collar 252 of the throttle rod 118. When the pump 1 discharges at point 102 fluid flows through a passage 119 to a passage 120 lifting the valve part 117 against the pressure of spring 115. When the flow is in the opposite direction the valve part 117 is seated and the orifices 116 and throttle rod 118 govern the rate of flow through it.

Valve 16 serves both as a safety valve and a quick-discharge valve. It is urged to closed position by a spring 121 and by fluid pressure in the

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upper chamber 122. The spring 121 may be adjusted by means of a nut 253 engaging a threaded pin 254 having an enlarged lower end 255 which engages the top of the spring 121. When the pressure at discharge point 101 acting against the annular shoulder 120 exceeds the combined force of spring 121 and of the pressure in the chamber 122 the valve 10 lifts permitting flow into internal passages 123 and 124. Interposed between passages 124 and 313 there is a check valve 30 urged to closed position by a spring 125. Valve 30 permits only one-way flow between passages 124 and 313 this flow being from the former to the latter passage when the pressure from beneath is sufficient to lift valve 30. The force of spring 125 may be varied by manipulation of a nut 257 engaging a threaded pin 258 which bears against a loose collar 259 engaging the top of the spring 125. An additional check valve 14 urged to closed position by a spring 127 permits only one-way flow between passages 123 and 119, the flow being from the former to the latter when the pressure differential is sufficient to overcome the force of the spring 127. It will be observed that passage 123 leads from valve 10 to passage 119 through check valve 14 and by-passes all other valves embodied in structure 10.

A pilot valve 26 controls the admission of pressure fluid to the upper chambers 111 and 122 of valves 13 and 16. The pilot valve 26 is actuated by a solenoid C. Under the influence of a spring 129 the valve stem 130 is urged to the raised position shown in Figs. 1, 2, 4 and 9, but when the solenoid C is energized the valve stem 130 is drawn downwardly to the position shown in Fig. 3. In the raised position the reduced portion 131 of the stem 130 uncovers the ports 132a and 132b and permits communication between pipes 133 and pipe 113 admitting pressure from pipe 133 to pipe 113 and thence to the top chamber 111 of valve 13. In the lowered position of valve stem 130 ports 132a and 132b are covered and ports 134a and 134b are uncovered by the reduced portion 135 of valve stem 130 permitting communication between pipe 136 and pipe 137 and hence admitting pressure to the top chamber 122 of valve 16. When the valve stem 130 is raised there is also communication from pipe 137 through port 134a and port 138 to discharge pipe 151.

Servo-motor system

The reciprocable element 103 which controls the position of the flow control member of the pump 1 through the medium of the servo-motor 2 moves within a centralizing cylinder 50. When the plunger 139 which is affixed to the reciprocable element 103 occupies the position represented in Fig. 2 which is midway between its limits of movement the flow control member of the pump 1 is maintained in the neutral or no-delivery position. Two collars 140 float within the centralizing cylinder 50. When pressure is admitted to the centralizing cylinder 50 through branches 141a and 141b of pipe 141 the floating collars 140 are urged towards each other until they each strike the abutment 142 within the cylinder which limits their movement. Such movement of the collars causes them also to engage the plunger 139 and to urge the reciprocable element 103 to its centralized position. Movement of the reciprocable element 103 may also be effected manually or electrically through a bell crank lever 53 connected at 143 to the end of reciprocable element 103 which projects beyond the centralizing cylinder 50. Fluid under a pressure

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of, say, eighty to one hundred pounds per square inch is supplied to the servo-motor 2 and the centralizing cylinder 50 by means of the pump 3. In the branch pipe 144 which joins pipe 141 and leads to the servo-motor 2 there is interposed a throttle valve 77 for controlling the flow of the hydraulic fluid to the servo-motor 2. Although no details of the servo-motor 2 have been illustrated, such devices being well known and commonly used in hydraulic systems, it will be understood that when fluid under pressure is admitted through pipe 144 the servo-motor 2 is in readiness to effect a movement of the flow control member of the pump 1 depending upon the position occupied by the reciprocable element 103, and that whenever the reciprocable element 103 is in its centralized position the servo-motor will maintain the flow control member of the main pump 1 in the neutral or no-delivery position. The servo-motor pump 3 at its suction side is connected to the pre-fill tank 92 through pipe 145 which has a shut-off valve 18 therein. It discharges through pipe 141 which has a check valve 22 therein permitting only one-way flow to the servo-motor 2 and centralizing cylinder 50. Connected to discharge pipe 141 is a pipe 146 which leads to a pressure switch 48 which closes the electric circuit to the main electric motor 5 when a predetermined pressure has been reached in the servo-motor system. Also connected to discharge pipe 141 is a pipe 147 leading to an air bottle accumulator 91 employed to build up and maintain pressure in the servo-motor system. Desirably the pipe 147 is provided with a drain valve 23 for draining the accumulator 91, and air valves 35 and 36 are provided in a pipe 148 leading to the top of the accumulator 91 for respectively admitting or discharging air from the accumulator.

Also connected to discharge pipe 141 is a pipe 149 leading through a restraining valve 21, a heat exchanger 43, a check valve 20 and a shut-off valve 76 to a pipe 149 which is connected to the pre-fill tank 92. Restraining valve 21 is used to permit the building up of a predetermined pressure in the servo-motor system. When the pressure in the system is such that there is no further flow therein it permits flow of the hydraulic medium through the heat exchanger 43, which heats or cools the liquid as desired, and returns it to the pre-fill tank 92. A relief valve 72 is desirably connected to pipe 149 to prevent excessive pressure from building up in the heat exchanger 43. An additional relief valve 39 connected to pipe 147 prevents pressure in the servo-motor system from increasing beyond a predetermined point. Both relief valves 39 and 72 discharge through pipes 150 and 151 to a drainage tank 152. A throttle valve 90 is inserted in each of branch pipes 141a, 141b.

Leakage system

The leakage system comprehends the drainage tank 152 and associated piping and instrumentalities including a mercoild liquid level switch 47 controlled by a float (not shown) in the drainage tank and serving to start and stop the motor 7 which drives the pump 4 and thus to control the height of the liquid in the drainage tank 152. The leakage system pump 4 draws liquid from tank 152 through pipe 153 and a check valve 25, or it may draw from the pre-fill tank 92 through pipe 154 and shut-off valve 74, and discharges through pipe 155, which has therein a filter 42 and a shut-off valve 75, to

the pre-fill tank 92. A pressure relief valve 78 connected to pipe 155 is employed to prevent the building up of excessive pressure between pump 4 and shut off valve 75 and safeguards against the contingency that the operator might accidentally start the pump 4 with the valve 75 closed. An air cleaner 44 is preferably associated with the drainage tank to filter the air therein. Connected to pipe 154 is a drain valve 19 employed to drain the pre-fill tank 92. Drain valve 19 may also be used as a suction connection between drainage tank 152 and the source of liquid supply for filling the pre-fill tank 92.

A combined throttle and stop valve 12 located on the operating panel 157 permits a bleeding down of the pull-back cylinders 29 of the press H. When the valve 12 is opened liquid in pipe 97 may be controllably bled through pipe 158 and thence through pipe 151 directly to the drainage tank 152, and hence the press platen may be lowered, whenever it may be desirable to do so, without starting the main motor 5. Liquid discharged from either of relief valves 39 and 72 drains to the tank 152 through pipes 150 and 151. Similarly, when the pilot valve 26 is in the raised position indicated in Fig. 2 of the drawings liquid may be discharged from the top chamber 122 of the quick-discharge valve 16 through pipe 137 and port 138 of pilot valve 26 to pipe 151 and thence to the drainage tank 152.

Manual control

For manually controlling the operation of the press H a hand lever 54 is used. This lever 54 is fulcrumed at 161 and has an arm 162 pivotally joined to the lower end of a control rod 163. At its upper end the control rod 163 is pivotally joined to the arm 164 of a three-armed bell crank lever 53 which swings about a fulcrum point 165. When the lever 54 is in the position represented in Fig. 2, the arm 164 of bell crank lever 53 occupies a horizontal position and the reciprocable element 103 of centralizing cylinder 50 is in its midway position within the cylinder 50. In an obvious manner a downward movement of the hand lever 54 produces an outward movement of the reciprocable element 103 within the cylinder 50 whereas an upward movement of the hand lever 54 produces an inward movement of the reciprocable element 103. Thus there is at all times and under all conditions a direct mechanical control over the functions of the servo-motor 2. Pivotally connected to the arms 164 and 167 respectively of bell crank lever 53 are the plungers 168 and 169 of solenoids B and A which effect the normal automatic control of the reciprocable element 103 through electrical circuits hereinafter described. The lower arm 170 of bell crank lever 53 engages a limit switch 80 and serves to close the switch 80 when the arm 170 is in the perpendicular position and otherwise to permit the switch to remain open. Affixed to the control rod 163 is a collar 81 adapted to be engaged by a bracket 164 projecting from the press platen 28 so that as the ram 26 travels upwardly and before reaching the top limit of its stroke the bracket 164 will come in contact with the collar 81 and force the control rod 163 upwardly in the event that the rod 163 has not already been moved to its fully raised position. A limit switch 82 is adapted to be mechanically engaged by the hand lever 54 and to occupy two positions dependent upon the position of the hand lever. When the hand

lever 54 is in its depressed position as represented in Figs. 1 and 3 the limit switch 82 is in "down" position. When the hand lever 54 is horizontal or is raised the limit switch 82 is in "up" position. Depending from the press platen 28 is a stroke rod 55 which has a cam 171 at its lower end which is adapted to engage an additional limit switch 70. When the ram is raised and the press H is fully open the limit switch 70 engages the cam 171 and is held open. Under other conditions the limit switch 70 is not engaged and remains closed.

Electrical system

On the instrument panel 157, as shown in Figs. 1 to 4, there are three push button type switches 66, 67 and 68. Switch 66 has start and stop buttons for operation of the main motor 5. Switch 67 has start and stop buttons for the motor 6 which drives the pump 3 of the servo-motor system. Switch 68 has start and stop buttons for the operation of the motor 7 which drives the pump 4 of the leakage system. Additional switches shown in the vicinity of the instrument panel are a cycle start button 62, an emergency stop button 63, and a foot actuated cycle start switch 69 the functions of which are more specifically described hereinafter.

With special reference to Fig. 5 the main electric motor 5 which drives the main pump 1 is represented as a synchronous motor energized by lines L¹, L² and L³ when the switch blades 173, 174 and 175 of relay R5 are closed. Connected to line L¹ is a wire 177 leading through solenoid 178 of relay R5, pressure switch 48, the stop element 179 of main motor switch 66, the starting element 185 of that switch and thence to wire 184, which leads through limit switch 80 to wire 186 which joins line L³. A wire 182 leads from line L¹ through solenoid 183 of relay R5 to wire 177. An additional wire 181 connected between the starting element 185 and stop element 179 leads through switch blade 180 to wire 186 and thence to line L³.

When and only when the pressure switch 48 is closed by reason of the existence of a predetermined pressure in the servo-motor system the main motor 5 may be started by closing the starting element 185 which allows current to flow from line L¹, through wire 177, solenoid 178, the pressure switch 48, the stop element 179 and starting element 185 of main motor switch 66, the limit switch 80, which is closed when the bell crank lever 53 is in its intermediate position shown in Fig. 2, and wire 186 to wire L³. This energizes solenoid 178 and closes switch blades 173, 174, 175 and 180 causing current to be supplied through lines L¹, L² and L³ to the main electric motor 5. Under this condition current also flows from line L¹ through wire 182 and solenoid 183 of relay R5 to wire 177, energizing relay R5 whereby the control circuits shown in Fig. 6 are rendered operative. When switch blade 180 has closed, solenoid 178 will remain energized through the holding circuit involving pressure switch 48, stop element 179, wire 181, switch blade 180 and wire 186, and the motor 5 will continue to run until the opening of either the pressure switch 48 or the stop element 179.

If desired, a speed control mechanism may be connected to the synchronous motor 5 in order to open the circuit by which the motor is energized in the event that a load is applied to the motor 5 before it has reached its maximum speed, but such a mechanism has not been illustrated

since it constitutes an adaptation which is not essential to the present invention.

The control circuit for operation of the press H is shown in Fig. 6. It comprehends two relays R1 and R2 and the switch blade 188 of relay R5, the solenoid 183 of which is shown in Fig. 5. All of the electrical instrumentalities are represented in the condition which they assume when the press is idle and in the position represented in Fig. 1. The operation of this circuit is described in connection with the description hereinafter of the operation of the press.

The electrical system for the leakage pump is shown in Fig. 7. Lines L¹, L², and L³ energize the motor 7 which drives the leakage pump 4 when the switch blades 190, 191 and 192 of relay R4 are closed. From line L¹ a wire 193 leads through the leakage motor starting switch 68 and through mercoild liquid level switch 47 to the solenoid 195 of relay R4 and thence to line L³. If the level of the liquid in the drainage tank 152 is below a predetermined point the mercoild liquid level switch 47 will be closed. The solenoid 195 may then be energized by closing the starting switch 68, or it may be de-energized by opening switch 68.

The electrical system for the servo-motor system is shown in Fig. 8. Lines L¹, L² and L³ energize the motor 6, which drives the servo-motor pump 3, when the switch blades 196, 197 and 198 of relay R3 are closed. From line L¹ a wire 199 leads through the solenoid 200 of relay R3 and thence through the stop element 201 of the start and stop switch 67 of the servo-motor system and through the starting element 202 of the same switch to wire 203 which joins line L³. When switch elements 201 and 202 are closed the solenoid 200 will be energized and the motor 6 will start. Moreover, through a holding circuit which includes switch blades 204 and wire 205 the solenoid will remain energized until the stop element 201 is actuated to break the circuit through wire 199 and solenoid 200.

Operation

The operation of the press H and the control system therefor is as follows.

In Fig. 1 the ram 26 and pull back plungers 30 of the press H are shown in their raised position at the upper limit of travel. All motors and pumps may be assumed to be idle and the various electrical switches and relays are as represented in Figs. 5, 6, 7 and 8. It may be assumed that the gate valve 9 is open admitting pressure at, say, thirty-five to forty pounds per square inch from the pre-fill tank 92 to the top of the press cylinder 27 and that high pressure fluid is trapped in the pull back cylinders 29, the valve 12 on the instrument panel 157 being closed.

Under these conditions the operator presses the start button of switch 68 of the leakage system so that the motor 7 which drives the leakage pump 4 may be energized whenever the liquid level in the drainage tank 152 is such as to cause the mercoild switch 47 to close. He also presses the start button of the servo-motor switch 67 closing the starting element 202 of that switch.

It will be particularly observed that if prior to attempting to start the main electric motor 5 the reciprocal element 103 is in any position other than a central position within the centralizing cylinder 50, such as represented in Fig. 1 of the drawings, the admission of pressure fluid to cylinder 50 through pipe 141 and branch pipes 141a and 141b will urge the floating collars 140

toward each other until they engage the plunger 139 and the abutment 142 causing the reciprocal element 103 to move to a central position, and hence insure that the flow control member of the main pump 1 is in the neutral or no-delivery position. Centralizing the reciprocal element 103 moves the bell crank lever 53 to a position where the arm 170 is perpendicular and engages limit switch 80 to close the same. Starting of the servo-motor pump 3 causes fluid under pressure to flow through pipe 141 and its branches 136, 144, 141a and 141b to the centralizing cylinder 50 and servo-motor 2. When the required predetermined pressure is reached in pipe 146 leading to pressure switch 48 of the servo-motor system, that switch will close. With the closing of the start element 185, of limit switch 80 and pressure switch 48 the circuit leading through wire 177 and solenoid 178 of relay R6 will be closed, starting main motor 5 which drives main pump 1.

The control circuit is now ready to function, and as soon as the pump 1 has reached its maximum speed the press operation can be started. All elements of the control system are now in the position represented in Fig. 2 of the drawings.

The press can be operated either manually by moving the hand lever 54, or electrically by pressing the start button 62 or the foot switch 69. By pressing either the cycle start button 62 or the foot switch 69 the press will be caused to move downwardly through the following operations. At this point the solenoid 183 of relay R5 is energized through the holding circuit shown in Fig. 5 which comprehends wire 186, switch blade 180, stop element 179, solenoid 183 and wire 182. The relay R5 being energized, switch blade 188 shown in Fig. 6 is closed. Current may flow from line L¹ through switch blade 188 of relay R5 to wire 208, thence through emergency stop switch 63 to wires 209 and 210 and through either the cycle start switch 62 or the foot switch 69, which ever may be closed, to wire 212 through solenoid 213 of relay R1 and thence to line L³. When relay R1 is energized its switch blades 214, 215 and 216 will close. The closure of switch blade 214 of relay R1 will establish a holding circuit for that relay through switch 227 of pressure governor 59, wire 235, switch blade 214, wire 228, solenoid 213 and wire 212. The closure of switch blade 215 will establish a circuit leading from wire 210 through wire 217 and switch blade 215 to line L³ through solenoid B. When solenoid B is thus energized its plunger 168 will be raised to the position shown in Fig. 3 and the bell crank lever 53 will cause the reciprocal element 103 to move outwardly, or to the left as shown in Fig. 3, which operates the servo-motor 2 and shifts the flow control member of the pump 1 to a position where that pump will discharge at connection 101. At the same time the resulting upward movement of the control rod 163 will cause a downward movement of the hand lever 54 and move limit switch 82 to "down" position. This completes a circuit through the switch 227 of pressure governor 59, wires 235 and 229 to switch 82 and thence through solenoid C of pilot valve 26 to line L³, energizing solenoid C.

Solenoid C being thus energized the valve stem 130 of pilot valve 26 will be drawn downwardly against the force of spring 129 to the position represented in Fig. 3 allowing fluid trapped in the top chamber 111 of check valve 13 to be released through pipe 113 and ports 132b and 138 of pilot valve 26 to discharge pipe 151 which leads to drainage tank 152. Draining the trapped fluid

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from chamber 111 allows check valve 13 to open under the influence of pressure in pipe 97 and permits fluid from pipe 97 to flow into passage 120 and thence through the ports 116 of throttle valve 17, which controls the closing speed of platen 28 by throttling the fluid passing through ports 116, to pump connection 102 which is now the suction side of the pump 1. If there is an insufficient flow of fluid passing by throttle valve 17 to the suction side of pump 1 to balance the flow at the discharge side, the check valve 14 will open and make up the discrepancy. Under the influence of pressure from pre-fill tank 92 through pipe 11 and filling check valve 8 and pressure from pump connection 101, which is now a discharge point, and pipe 98 the ram 26 will be urged downwardly.

When the press platen 28 moves downwardly the cam 171 on the stroke rod 55 disengages limit switch 70 which has heretofore been held open by engagement with cam 171. This allows limit switch 70 to close and permits current to flow from wire 210 through wire 218, switch blade 216 of relay R1, wire 219, limit switch 70 and wire 220 through solenoid 221 of relay R2 and thence to line L³. Relay R2 being energized its switch blades 222 and 223 will be closed and its switch blade 224 will open. Moreover relay R2 will remain energized through a holding circuit from wire 210 through switch blade 222 of relay R2, wire 219, limit switch 70, wire 220 and solenoid 221.

When the press platen 28 has moved downwardly to the point where it is stalled or has come in contact with the work piece W, as shown in Fig. 3, the movement of fluid in the pipes 97 and 98 ceases momentarily. When flow ceases from pre-fill tank 92 through filling check valve 8 this valve will close and permit high pressure fluid from pump connection 101 and pipe 98 to be trapped in press cylinder 27. The press platen 28 continues to be urged downwardly upon the work piece W under the intensified pressure until that pressure has reached the predetermined point for which the pressure governor 59 is set. At this point pressure in the pipe 99 causes pressure governor 59 to operate opening switch 227 and hence opening the holding circuit which leads through wire 235, switch blade 214 and wire 228 to solenoid 213 of relay R1, de-energizing relay R1, opening switch blade 215 and de-energizing solenoid B. Similarly the circuit leading from the switch 227 of pressure governor 59 through wires 235 and 229 and through limit switch 82 to solenoid C will be opened de-energizing solenoid C, and causing the valve stem 130 to pilot valve 26 to be raised under the influence of spring 129.

At this point solenoids A and B being de-energized, bell crank lever 53 will be moved under the influence of pressure in the centralizing cylinder 50 first to a central position in which the limit switch is disengaged by the hand lever 54 and hence moved to the "up" position closing the circuit from wire 210 and switch blade 223 through wire 225, limit switch 82 and solenoid A. This energizes solenoid A and causes a further movement of bell crank lever 53 to the position represented in Fig. 4.

Energizing solenoid A moves the reciprocable element 103 inwardly causing the flow control member of the pump 1 to be shifted so that pump connection 101 becomes the suction side and pump connection 102 becomes the discharge side, and the flow of fluid is as represented in Fig. 4. Solenoid C being de-energized, the valve stem 130 of pilot valve 26 is raised causing fluid trapped

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in the upper chamber 122 of valve 16 to be discharged through pipe 137 and ports 134a and 138 of pilot valve 26 to pipe 151 and thence to drainage tank 152.

The pressure against the annular shoulder 126 at the lower end of valve 16 will then be sufficient to raise valve 16 against the pressure of spring 121 releasing pressure from pipe 98 and pump connection 101 and allowing fluid to pass through valve 16 and to flow through pipe 230 and passage 123 in the valve structure 10. Pressure in the main press cylinder 27 is thereby gradually relieved. A decompression of the fluid is caused, and this prevents the shock which would otherwise be attendant upon the sudden release of pressure.

Fluid discharged at pump connection 102 raises valve 17 from its seat and flows from passage 119 to passage 120 in the valve structure 10. The pressure is sufficient to raise valve 13 from its seat so that the fluid flows through pipe 97 into the pull back cylinders 29. The same pressure is applied through pipe 94 to the filling check valve 8 causing it to open. In an obvious manner pressure applied to the plungers 30 of the pull back cylinders 29 lifts the platen 28 together with the ram 26 forcing fluid out of the main cylinder 27 of the press H into the pre-fill tank 92 through pipe 11.

As soon as the platen 28 in its upward movement has reached the point where the cam 171 on stroke control rod 55 engages the limit switch 70 this switch will open. Opening of the limit switch 70 breaks the circuit, shown in Fig. 6, leading through wire 220 to solenoid 221 of relay R2. When relay R2 thus becomes de-energized, switch blade 223 will open, breaking the circuit through wire 225 and limit switch 82 and de-energizing solenoid A. Pressure in the servomotor system applied to both ends of the centralizing cylinder 50 will immediately shift the reciprocable element 103 to its central position and shift the flow control member of the pump 1 to the neutral position. Accordingly the press H will come to rest and remain in the open position. The cycle is now ready to be repeated.

Should the limit switch 70 fail to function for any accidental or unforeseen reason, the platen 28 would continue to move upwardly and the solenoid A would remain energized. To prevent this from occurring the bracket 164 attached to the platen 28 comes in contact with the collar 81 on the control rod 163 forcing this rod upwardly overcoming the force of the solenoid A and moving the hand lever 54 downwardly until it comes in contact with the limit switch 82 moving that switch to its "down" position breaking the circuit through wire 225 and switch 82 and de-energizing solenoid A.

At any point in the operation the press may be stopped by actuating the emergency stop button 63. When the emergency stop button 63 is pressed all circuits leading to the switch blades of relays R1 and R2 are opened except that the circuit leading to switch blade 224 of relay R2 is closed. With the switch 63 pressed downwardly the latter circuit is closed through wire 231, switch blade 224 of relay R2 and solenoid A.

When the press H is idle and the main motor 7 has been shut down if it is desired to move the platen 28 to closed position this may be done by opening the valve 12 on the instrument panel 157. Opening the valve 12 permits pressure fluid to be discharged from the pull back cylinders

29 through pipe 97 to pipes 158 and 151 and thence to drainage tank 152.

When the press is electrically operated the condition of the solenoids A, B and C is as represented in the following table:

When the press is moving up, solenoid A is energized; solenoid B is de-energized; solenoid C is de-energized (limit switch 82 being in the "up" position).

When the press is moving down, solenoid A is de-energized; solenoid B is energized; solenoid C is energized (limit switch 82 being in the "down" position).

When the press is stationary, solenoid A is de-energized; solenoid B is de-energized; solenoid C is de-energized (limit switch 82 being in the "up" position).

Manual operation of the press through manipulation of hand lever 54 may be effected at any time while the main motor 5 is running. Any movement of the hand lever 54 will predominate over the forces exerted on the bell crank lever 53 by solenoids A and B. When hand lever 54 is raised or depressed manually the reciprocable element 103 is moved inwardly or outwardly by direct mechanical leverage. Incident to such movements the limit switch 82 is moved to its "up" or "down" positions, opening or closing the circuit leading through solenoid C and operating pilot valve 26 in the desired manner.

When the press H is manually operated the condition of solenoids A, B and C is as represented in the following table:

When the press is moving up, solenoid A is de-energized; solenoid B is de-energized; solenoid C is de-energized (limit switch 82 being in the "up" position).

When the press is moving down, solenoid A is de-energized; solenoid B is de-energized; solenoid C is energized (limit switch 82 being in the "down" position).

When the press is stationary, solenoid A is de-energized; solenoid B is de-energized; solenoid C is de-energized (limit switch 82 being in the "up" position).

While I have described in some detail a preferred embodiment of my invention it will be apparent that various modifications may be made in the system herein described and illustrated without departing from the spirit of the invention, and that certain features of the invention may be used to advantage without use of other features, and that the invention may be applied to various types of hydraulic machinery other than the particular type of press illustrated in the drawings.

Having thus described my invention, I claim:

1. In a control system for a hydraulically operated machine including an electric motor and a reversible pump driven thereby for supplying pressure fluid to said machine, said pump having a flow control member and means for shifting the same from neutral to on-stroke position; a pressure-urged reciprocable element connected to said shifting means and governing through it the direction and delivery of said pump, an electric circuit for supplying current to said motor, and means interposed in said circuit for preventing starting of the motor unless as a condition precedent the reciprocable element has been urged to a position which maintains the flow control member of the pump in neutral position.

2. In a control system for a hydraulically operated machine including an electric motor and a reversible pump driven thereby for supplying

pressure fluid to said machine, said pump having a flow control member and means for shifting the same from neutral to on-stroke position, a centralizing cylinder having therein a reciprocable element connected to said shifting means and governing through it the direction and delivery of said pump, an electric circuit for supplying current to said motor, and means interposed in said circuit for preventing starting of the motor unless as a condition precedent pressure has been admitted to said centralizing cylinder to maintain the flow control member of the pump in neutral position.

3. In a control system for a hydraulically operated machine including an electric motor and a reversible pump driven thereby for supplying pressure fluid to said machine, said pump having a flow control member and servo-motor for shifting the same from neutral to on-stroke position, a centralizing cylinder having therein a reciprocable element connected to said servo-motor and governing through it the direction and delivery of said pump, means for supplying pressure fluid simultaneously to said servo-motor and centralizing cylinder, an electric circuit for supplying current to said electric motor, and means interposed in said circuit for preventing starting of the motor unless as a condition precedent pressure has been admitted to said centralizing cylinder to maintain the flow control member of the pump in neutral position.

4. In a control system for a hydraulically operated machine including an electric motor and a reversible pump driven thereby for supplying pressure fluid to said machine, said pump having a flow control member and means for shifting the same from neutral to on-stroke position, a centralizing cylinder having therein a reciprocable element connected to said shifting means and governing through it the direction and delivery of said pump, means mechanically connected to said reciprocable element for governing the desired sequence of operations of the pump, an electric circuit for supplying current to said electric motor, and means interposed in said circuit for preventing starting of the motor unless as a condition precedent pressure has been admitted to said centralizing cylinder to maintain the flow control member of the pump in neutral position.

5. In a control system for a hydraulically operated machine including an electric motor and a reversible pump driven thereby for supplying pressure fluid to said machine, said pump having a flow control member and means for shifting the same from neutral to on-stroke position, a centralizing cylinder having therein a reciprocable element connected to said shifting means and governing through it the direction and delivery of said pump, electro-mechanical means connected to said reciprocable element for automatically effecting the desired sequence of operations of the pump, manually operated means also connected to said reciprocable element for operating the pump according to the will of the operator, an electric circuit for supplying current to said electric motor, and means interposed in said circuit for preventing starting of the motor unless as a condition precedent pressure has been admitted to said centralizing cylinder to maintain the flow control member of the pump in neutral position.

6. In a control system for a hydraulically operated machine including a reversible pump for supplying pressure fluid to said machine, said

pump having a flow control member and pressure operated means for shifting the same from neutral to on-stroke position, a multi-position reciprocable element connected to said shifting means and governing through it the direction and delivery of the pump, fluid pressure means for urging said reciprocable element towards its neutral position whenever pressure is admitted to said shifting means, electro-mechanical means connected to said reciprocable element for automatically effecting the desired sequence of operations of the pump, and a manually operated predominantly controlling device, including a multi-position control element, having a direct mechanical connection with said reciprocable element for shifting the same to neutral or either on-stroke position whereby the pump may at all times be controlled manually at the will of the operator.

7. In a control system for a hydraulic press or the like having a reciprocating platen and cylinder means for moving said platen in opposite directions, means including a reversible pump for supplying fluid, varying in pressure and direction, to the cylinder means of said press, two spaced connections on said pump, each serving either as a suction or discharge point and having communication with said cylinder means through pipe lines leading thereto, a set of valves arranged in juxtaposed relation between said spaced connections, means for operating said valves in predetermined sequence to control the direction of flow in the pipe lines to and from the press, said valves including a throttle valve for controlling the quantity of fluid flow in one of said lines, and said valves being embodied in a unitary structure mounted on said reversible pump and having internal passages by which the valves are serially connected, and an additional internal passage in said structure leading from one pump connection to the other and by-passing the throttle valve aforesaid.

8. In a control system for a hydraulic press or the like having a reciprocating platen and cylinder means for moving said platen in opposite directions, means including a reversible pump for supplying fluid, varying in pressure and direction, to the cylinder means of said press, two spaced connections on said pump, each serving as a suction or discharge point and having communication with said cylinder means through pipe lines leading thereto; a set of valves arranged in juxtaposed relation between said spaced connections

posed relation between said spaced connections with inter-communicating passages between said valves, said valves and passages being embodied in a unitary structure, mounted on said reversible pump and including a quick discharge valve serving to prevent shock when pressure is released in said cylinder means, and means for operating said valves in predetermined sequence to control the direction and pressure of fluid flow in the pipe lines to and from the press.

9. In a control system for a hydraulically operated machine including a reversible pump for supplying pressure fluid to said machine for its operation, said pump having a flow control member and pressure operated means for shifting the same from neutral to on-stroke position, a multi-position reciprocable element connected to said shifting means and governing through it the direction and delivery of the pump, fluid pressure means for urging said reciprocable element towards its neutral position whenever pressure is admitted to said shifting means, electro-mechanical means connected to said reciprocable element and having a force sufficient to overcome the force of said fluid pressure means and thereby effect the desired sequence of operations of the pump, and a manually operated predominantly controlling device, having a direct mechanical connection with said reciprocable element for shifting the same to neutral or either on-stroke position whereby the pump may at all times be controlled manually at the will of the operator.

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