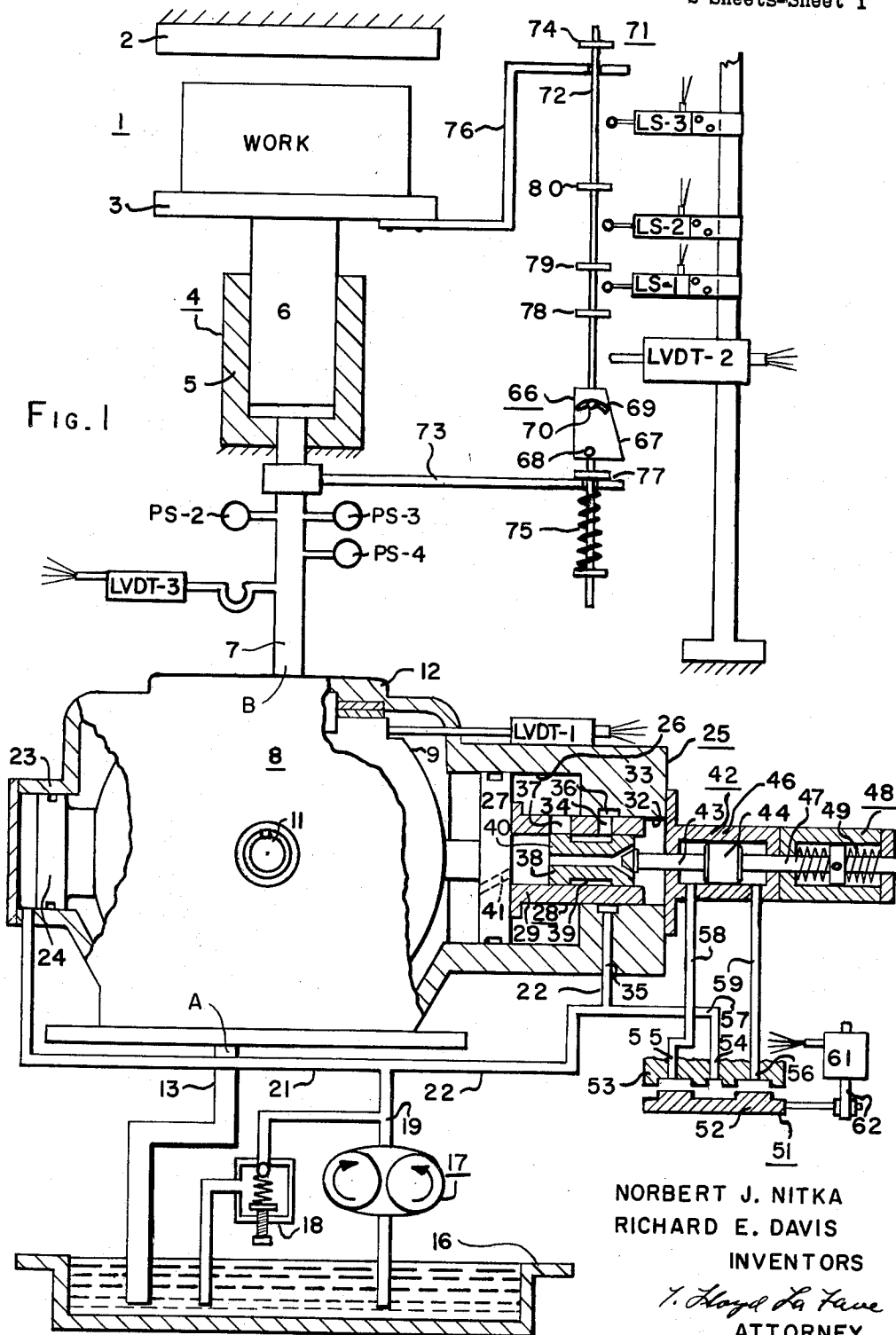


3,026,677

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N. J. NITKA ETAL
PRESS CONTROL

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2 Sheets-Sheet 2

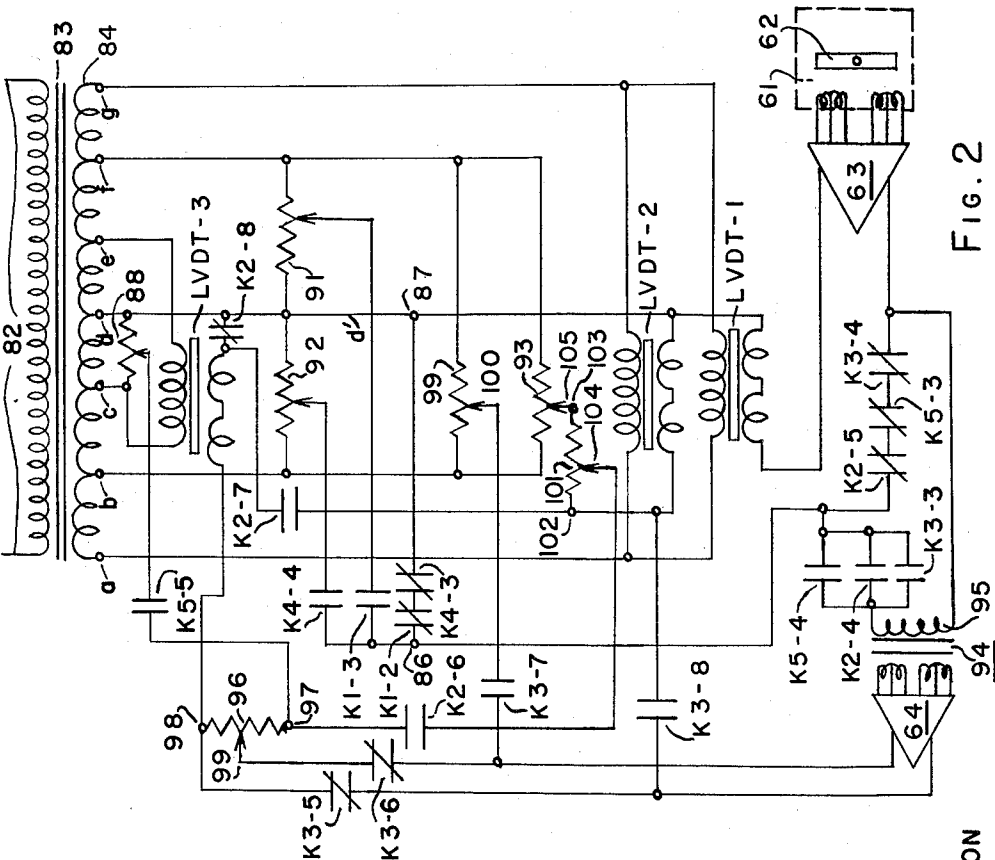


FIG. 2

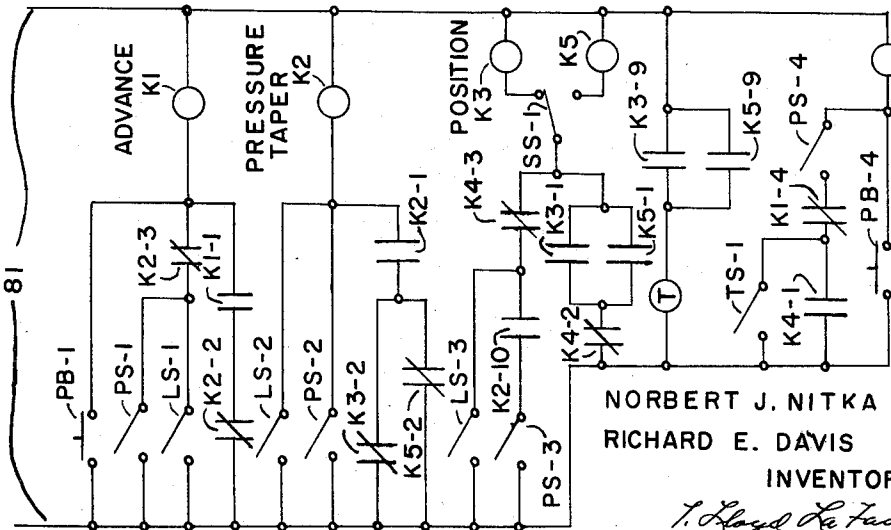


FIG. 3 DECOMPRESSION

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1

3,026,677

PRESS CONTROL

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7 Claims. (Cl. 60—52)

This invention relates to an electrohydraulic control system for a hydraulic press and more particularly to the control of the working stroke of the press.

The control system of this invention is particularly suitable for a hydraulic press employed for a work forming operation or for pressing where the work is resilient and yielding, and where the work reaction force diminishes in time for a given displacement. This control system may be adapted to conventional presses for forming and shaping any material parts and particularly may be adapted to conventional presses for compressing wood fibers in the making of consolidated wood products.

The hydraulic press has a pair of relatively movable platens, and the movable platen is actuated by a hydraulic ram for compressing a work disposed in the press. The control system controls the admission of pressure fluid to the hydraulic ram so as to vary the pressure and the position of the ram in a predetermined manner.

It is an object of the invention that the control system automatically vary the pressure on the work in accordance with its displacement and limit the final displacement.

Another object of the invention is to provide a press control system that is sensitive to minute changes in applied pressure and displacement so that within a range of the working stroke of the press the pressure varies as a function of the displacement.

Another object of the invention is to provide a hydraulic press with a sensitive electrohydraulic control of motive fluid utilizing opposed electric signals produced in accordance with applied pressure and position so as to maintain the signals equal.

Another object of the invention is to provide an electrohydraulic control system for a press that tapers the pressure applied to the work for a predetermined distance and then controls the pressure applied so as to hold the movable platen in a predetermined final work position.

Another object of the invention is to provide such a control that tapers the pressure applied until the movable platen attains a predetermined position and then holds a predetermined pressure on the work.

Other objects and advantages will be apparent upon a reading of the following description taken with the accompanying drawings, in which:

FIG. 1 shows a hydraulic press control system with the components thereof schematically arranged and with hydraulic control portions of a supply pump therefor shown in cross section. FIG. 2 shows an electric control circuit including electric components shown in FIG. 1 for controlling the hydraulic control means of FIG. 1, and FIG. 3 is an electric circuit including electric components shown in FIG. 1 for controlling the energization of solenoids having contacts in the electric control circuit of FIG. 2.

Referring to the drawings, the invention is shown comprising a hydraulic press, a source of motive power for the press, and a control system for the operation of the press. The hydraulic press 1 has a stationary platen 2 and a movable platen 3. Since the movable platen 3 is the lower platen, it may be actuated by a single acting main ram 4 for a working stroke and be actuated by the force of gravity for the return stroke. A double acting

2

main ram could be employed instead, as is well known, but the function of the single acting ram as all that is necessary for an understanding of the present invention.

The portion of the press control that this invention relates to is primarily the pressing or working stroke portion of the cycle of operation. The movable platen 3 is brought to the initial work position in a conventional manner, such as by auxiliary cylinders, not shown, for rapidly advancing the platen 3 and a surge valve, not shown, for prefilling the main ram cylinder 5. When the pressure in the auxiliary cylinders attains a predetermined value, a pressure switch PS-1, shown only in a solenoid control circuit, effects closing of the surge valve and initiates control of a main hydraulic pump 8 for supplying motive fluid to ram cylinder 5 for the working stroke of the press.

Pump 8 is a rotary positive displacement pump having a variable displacement member and may be an axial type of pump or, as shown, a radial type whose displacement member is a slideblock 9 rigid with the pump reaction ring whose eccentricity to the pump rotor determines the stroke of the pump, such as is shown in U.S. Patent 2,406,138.

Slideblock 9 is arranged in pump casing 12 for movement transversely of the pump rotor. When the reaction ring is concentric with the pump rotor and shaft 11, the slideblock is in a neutral position and the pump has zero stroke. Displacement of the slideblock 9 to the left of its neutral position puts the pump on stroke so that it discharges in one direction which is from port A to a channel 13, and the pump inlet is port B that is connected to a channel 7. Displacement of the slideblock 9 to the right of its neutral position puts the pump on a "reverse" stroke so that it discharges in an opposite direction which is from port B and the pump inlet then is port A and channel 13. A reservoir 16 for pump fluid and control fluid is represented schematically.

Control pressure fluid is supplied by an auxiliary pump such as a gear pump 17 driven in unison with main pump 8. A relief valve 18 is connected to gear pump discharge line 19 of the relief valve to limit the pressure of the gear pump control fluid to a predetermined relatively low value such as 75 p.s.i.

A slideblock positioning means comprises a bias cylinder 23 and a control cylinder 26 disposed in opposite sides of the pump casing. The bias cylinder 23 on the left side has a piston 24 abutting the slideblock 9 to apply a constant force thereto for urging the slideblock toward the right. A branch conduit 21 connects bias cylinder 23 to discharge line 19 of gear pump 17.

The control cylinder 26 has a control piston 27 substantially larger than the bias piston 24, and when gear pump pressure is applied thereto, the control piston overcomes the bias piston to move the slideblock toward the left. The control cylinder 26 includes a follow-up type valve 28 controlling the flow of fluid to and from control cylinder 26 to modulate the force of the control piston 27 to hold the slideblock in a command position. The discharge line 19 from the gear pump is connected by branch channel 22 to passage 35 in the end head 33 of the control cylinder and through the follow-up valve 28 into the control cylinder 26.

The follow-up valve 28 comprises a valve sleeve 29 and a valve plunger 38 each movable axially of the other. Valve sleeve 29 is disposed in a bore 32 in end head 33 that is coaxial of control piston 27 and valve sleeve 29 is secured to the control piston 27 for axial movement therewith. The valve plunger 38 is disposed within valve sleeve 29 and is axially positioned therein by a pilot control means 42 and normally positioned by a spring centering device 48.

The valve plunger 38 has a pair of axially spaced lands

that define a pressure chamber 39 therebetween. An inlet hole 34 through sleeve 29 remains in communication with chamber 39 of the plunger. Inlet hole 34 in the valve sleeve remains in communication with a passage 36 in the end head that is connected to branch supply channel 22 from gear pump 17 and thereby maintains pressure chamber 39 supplied with pressure fluid.

Control port 37 in valve sleeve 29 is open to cylinder 26 and remains in communication therewith. Control port 37 is normally blocked by the left land 40 of the pair of lands defining the pressure chamber 39. The space to the left of valve plunger 38 is open through suitable drain passages 41 to drain to the reservoir 16. Movement of plunger 38 to the left relative to port 37 admits control pressure fluid to control cylinder 26 and movement of plunger 38 to the right relative to port 37 connects control cylinder 26 to drain. Upon valve plunger 38 being displaced to the left, it uncovers valve sleeve port 37 to admit gear pump pressure fluid to the control cylinder 26; this causes the control piston 27 to move to the left a corresponding amount until the sleeve port 37 is again blocked by the left valve land as the sleeve follows the piston 27. Upon valve member 38 being displaced to the right, the left land uncovers valve sleeve port 37 and fluid discharges from control cylinder 26 to drain; this causes the constant fluid pressure which acts on the pump bias piston 24 to force the slide block 9 and control piston 27 to the right until the valve sleeve port 37 is again blocked by the left valve land.

The valve member 38 of the follow-up type valve 28 is connected by rod 43 to the pilot control means 42 and centering device 48. The pilot means 42 comprises a piston 44 in a cylinder 46 mounted on end head 33. Pilot piston 44 is double acting, and its rod 43 extends through centering device 48 to serve as its shaft. The centering device comprises a conventionally arranged caged spring 49 effective to urge the valve member 38 to a position that commands the pump displacement member to neutral or zero stroke position.

Gear pump control pressure is admitted to either end of the pilot cylinder 46 through a servo valve 51 for positioning the pilot piston 44 against the force of the caged centering spring 49. The servo valve 51 is preferably of the flat faced type described in U.S. Patent 2,939,483, and comprises a valve plate 52 and a valve block 53 having opposed flat faces with flow control lands and chambers therein. The valve block has a pressure supply port 54 open between a pair of lands of the valve plate and connected to a branch conduit 57 from the source of control pressure provided by the gear pump 17. A pair of control ports 55, 56 in the valve block are normally blocked by the lands of the valve plate and are connected respectively to opposite ends of the pilot cylinder by conduits 58, 59.

The servo valve is actuated and controlled by a torque motor 61 whose armature 62 is connected to actuate the valve plate 52 of the servo valve 51. The displacement of the armature 62 of the torque motor varies in accordance with the value and sense of the power supplied to it by an electric amplifier 63. The power output of the torque motor is relatively very small but is sufficient to operate the servo valve 51 which in turn controls the flow of control pressure fluid to the pilot cylinder 46.

The torque motor 61 is energized by the output of the electric power amplifier 63 which is preferably of the type disclosed in U.S. Patent 2,973,468, issued February 28, 1961, and also assigned to the assignee hereof.

The electric control circuits are shown in FIGS. 2 and 3. Switching means and signal providing components associated with the pump, and with ram pressure and ram position are shown in FIG. 1 as well as shown schematically in the electric circuits. Linearly variable displacement transformers are used, and each is designated an LVDT. Pump LVDT-1 is mounted on the pump casing 12 so that the movable member or displacement

member of LVDT-1 is urged against a face of the pump slide block so as to follow pump displacement. Pump LVDT-1 is a signal transmitter whose output signal varies in accordance with the pump stroke.

Ram LVDT-2 is positioned so that its movable member is displaced by a cam 66 of a platen follower 71 during closing of the press on the work. Ram LVDT-2 is, therefore, a signal transmitter whose output signal varies in accordance with the position of the ram 6 and the movable platen 3, and therefore also according to the degree of closing of the press.

Pressure LVDT-3 is part of a pressure transducer comprising a Bourdon tube connected to ram cylinder supply line 7. The Bourdon tube actuates the movable member of LVDT-3 in accordance with the pressure in line 7. LVDT-3 therefore provides an output electric signal in accordance with the pressure of motive fluid supplied to the ram cylinder 6.

The platen follower 71 comprises a rod 72 adapted to follow any predetermined movement of the platen 3. The rod is guided and supported for vertical movement in stationary supports 73, 76. A collar 74 is detachably mounted on the follower rod at a position such that an arm 76 movable with platen 3 will engage the collar 74 and carry the rod 72 along with the platen when the platen has been advanced to a predetermined position.

The follower rod 72 is urged by a spring 75 toward a lower position at which a stop collar 77 on rod 72 rests on a stationary support 73. Other adjustably positioned collars 78, 79, 80 on rod 72 serve as abutment contacts adapted to sequentially engage limit switches LS-1, LS-2, LS-3, respectively, during the working stroke of the press.

The platen follower also includes cam 66 positioned on follower rod 72 so as to displace the movable member of ram position LVDT-2 during a predetermined portion of the working stroke of the press. Cam 66 has an inclined cam surface 67 whose angle of inclination may readily be varied by rotation of the cam about a support pivot 68, within the limits permitted by arcuate slot 69 and a fastening screw 70 extending therethrough. The cam may be positioned, for example, to give a 1/2" displacement of the LVDT-2 member.

The platen 3 may be rapidly advanced to a position engaging the work by means of rapid advance or auxiliary cylinders, not shown. When the platen is in a position where the working stroke is to begin, a first switch means comprising a limit switch LS-1 is actuated by a contact 78 on the platen follower to connect relay K1 to voltage source 81. Relay K1 causes the pump to have a predetermined stroke for supplying motive fluid to ram cylinder 6 for advancing the press and compressing the work.

When the platen 3 has advanced to a predetermined work position, another contact 79 on the follower rod actuates a limit switch LS-2 to connect relay K2 to voltage source 81. While relay K1 has contacts K1-1 in a holding circuit for relay K1, relay K2 has contacts K2-1 in a holding circuit for relay K2 and also contacts K2-2 in the holding circuit for relay K1 to disconnect relay K1 when relay K2 is energized. Relay K2 places in operation the control circuit that causes the pump to vary its stroke with advance of platen 3 so as to reduce the pressure of the motive fluid supplied to the press ram in accordance with the movement of the ram and displacement of the work.

Such pressure-taper control is changed to a platen or ram position control when the platen has attained a predetermined work position under pressure taper control at which a limit switch LS-3 is actuated by a contact 80 on the platen follower to connect relay K3 to the voltage source 81. Relay K3 has its own holding circuit through contacts K3-1 and has contacts K3-2 to disconnect relay K2. Relay K3 causes the control circuit to

5

control the stroke of the pump so as to bring the platen 3 to a predetermined final work position and to hold it there until relay K4 is energized to cause decompression of the ram cylinder. Relay K4 is preferably connected by a timing switch TS-1 a given interval of time after the platen has attained the final work position.

The control circuit provides the voltage signals to the amplifier to energize the torque motor controlling the hydraulic stroke control system. This control circuit or network includes a source 82 of control voltage to a control voltage supply transformer 83 having a secondary winding 84 with multiple taps *a, b, c, d, e, f* and *g*, with outer pair of taps *a, g* intermediate pair of taps *b, f* and low voltage pair of taps *c, e* and a center tap *d* that is in the center of the secondary winding represented by each pair of taps.

An "advance" command potentiometer 91 has input terminals connected to center tap *d* and tap *f*, and a reverse or "decompression" potentiometer 92 has input terminals connected to center tap *d* and tap *b*. A "pressure-taper" command potentiometer 93 and "position" command potentiometer 99 have input terminals connected to pair of taps *b, f*.

Signal transmitters LVDT-1 and LVDT-2 have primary windings connected to relatively high voltage taps *a, g*, and signal transmitter LVDT-3 has its primary winding connected to low voltage pair of taps *c, e*.

FIG. 2 shows that a common or neutral line *d*¹ is connected to center tap *d* of the transformer 83 and includes a terminal 87 of a slideblock control circuit, comprising amplifier 63 and pump LVDT-1 which are normally connected in a closed loop circuit through contacts K3-4, K5-3, K2-5 in another line of the closed loop slideblock control circuit having a terminal 86. Contacts K1-2, K4-3 normally shunt terminals 86, 87. Since the pump slideblock is normally at zero stroke, LVDT-1 would have no output signal and the torque motor 61 would be inoperative.

Relay K1, when energized, introduces a command signal voltage from preset potentiometer 91 into the slideblock control circuit, for the shunt contacts K1-2 are opened and contacts K1-3 are closed to connect the adjustable tap of potentiometer 91 to terminal 86. This command signal causes the pump to go to a stroke at which the pump LVDT-1 provides an equal and opposite signal to that of potentiometer 91. At this pump stroke the pump advances the press toward closing and compresses the work at a fixed rate.

When the press has advanced toward closing to a predetermined work position, a switch means comprising a contact 79 on follower rod 72 actuates a limit switch LS-2 to cause energization of relay K2. Relay K2 establishes its own holding circuit through contacts K2-1, and opens contacts K2-2 to disconnect the holding circuit for relay K1 and operatively disconnect the slideblock position control.

The slideblock control circuit is again shunted by contacts K1-2, K4-3 between terminals 86, 87, and the secondary winding 95 of a coupling transformer 94 is inserted in this slideblock control circuit by opening of contacts K2-5 which shunt the secondary winding 95 and by closing of contacts K2-4 which normally operatively disconnect the secondary winding 95. The coupling transformer 94 serves to introduce command signals into the slideblock control circuit, and such command signals are pressure commands which consist essentially of the pressure error signals, which are the difference between the ram position signals and the pressure signals provided by LVDT-2 and LVDT-3, respectively.

The output of ram position LVDT-2 is connected in series with the resistance element of a trim potentiometer 101 and the adjustable tap 105 of the preset command potentiometer 93.

The output of the trim potentiometer 101, represented by terminal 102 and adjustable tap 104, and the output

6

winding of the pressure LVDT-3 are connected in a closed loop series circuit with the input terminals 97, 98 of a pressure gain potentiometer 96 by operation of relay K2 which closes contacts K2-6 and K2-7 and opens contacts K2-8 and which normally ground LVDT-3 to neutral line *d*¹. The output terminals 98, 99 of the pressure gain potentiometer 96 are connected to the signal input terminals of the preamplifier 64, and therefore, the resultant signal provided by the ram position LVDT-2 and pressure LVDT-3 is the command signal impressed on the slideblock control circuit through preamplifier 64 and transformer 94.

It may be noted that pressure LVDT-3 has its energizing winding connected to low pressure taps *c, e* of the transformer 83; whereas the energizing winding of ram position LVDT-2 is connected to relatively high voltage taps *a, g* of transformer 83. The trim potentiometer 101 reduces the voltage from the ram position LVDT-2 circuit to the voltage capacity range of pressure LVDT-3 so that in the output circuit of the trim potentiometer 101 the difference in the voltages is the pressure error signal transmitted to the pressure gain potentiometer 96. The pressure error signal is impressed on the input terminals 97, 98 of the pressure gain potentiometer 96 whose output terminals 98, 99 are connected to the signal input terminals of the preamplifier. Pressure gain potentiometer 96 is adjustable and preset to apply a proportion of the pressure error signal for controlling the output of the preamplifier which provides a command signal to the slideblock control circuit to cause the pump stroke and therefore pump discharge pressure to vary until pressure LVDT-3 produces a signal to minimize the difference between the pressure signal from LVDT-3 and the ram position signal in the pressure signal circuit, and to thereby eliminate the pressure error signal. Thus as the ram forces movable platen 3 to advance against the work, the cam 66 further displaces the movable member of the ram position LVDT-2 and commands the pump stroke control to decrease pump discharge pressure in accordance with such ram press closing movement.

Finally, as platen 3 attains a predetermined position, a contact 80 on the follower rod 72 actuates the limit switch LS-3 to energize relay K3.

Ram position control is established by relay K3. Relay K3 closes contacts K3-1 to establish its holding circuit, and it opens contacts K3-2 to disconnect the holding circuit for relay K-2 and thereby operatively disconnecting the pressure taper control previously described. Contacts K3-5 and K3-6 in the preamplifier circuit are also opened to isolate the pressure gain potentiometer 96 therefrom. Relay K3 also closes contacts K3-7 to connect tap 100 of preset ram position command potentiometer 99 to one terminal of the preamplifier and relay K3 closes contacts K3-8 to connect terminal 102 of the ram position LVDT-2 to the other terminal of the preamplifier and thereby provide the ram position control command to the slideblock control circuit. The preamplifier output is retained in the slideblock control by operation of relay K3 which closes contacts K3-3 which parallel contacts K2-4, and which also opens contacts K3-4 which are in series with contacts K2-5. The position error signal command is the difference between the preset command voltage provided by potentiometer 93 and the ram position signal voltage provided ram position LVDT-2, which is actuated by cam 66 in proportion to ram movement. Therefore, the position control provides a command signal from potentiometer 99 that orders the ram to a predetermined final work position irrespective of applied pressure or of the final position obtained under pressure taper control. The difference between the position command voltage of potentiometer 99 and the position signal voltage provided by ram position LVDT-2, that is, the algebraic sum of their voltages, is the position error voltage that commands the slideblock control through the preamplifier to

vary pump stroke so as to minimize the position error signal voltage.

A timing device T is started by closing of contacts K3-9 upon energization of relay K3, and the timing device T is operative after a predetermined interval of time to actuate a switch TS-1 that causes energization of relay K4 for effecting decompression of the ram cylinder. Relay K4 is provided with a holding circuit comprising its own contacts K4-1 and also normally closed contacts K1-4 of relay K1. Relay K4 opens the holding circuit for relay K3 thereby disconnecting and shunting the secondary winding 95 of transformer 94. Relay K4 opens contacts K4-3 and closes contacts K4-4 to complete the slideblock control circuit so that it includes the amplifier 63 in series with the output winding of pump LVDT-1 and a preset command potentiometer 92 whose voltage signal causes the pump slideblock to be positioned in an opposite direction so that the pump discharge is to reservoir 16 and pump suction is the line 7 to the ram cylinder. When the pressure in the line 7 to the ram cylinder has dropped to a predetermined low value, a normally closed pressure switch PS-4 is opened thereby to operatively disconnect relay K4. The pump slideblock is then returned to zero stroke or neutral position by the bias force provided by the caged spring 49 which centers the pilot piston.

The solenoid control circuit shows a pushbutton switch PB-1 for putting relay K1 under the manual control of an operator. Similar operator controlled pushbutton switches, not shown, may be included in each of the relay circuits.

The first switch means may comprise a pressure switch PS-1 in lieu of or in addition to the limit switch LS-1 and be arranged so that the pressure switch PS-1 will close to assure operation of relay K1 when the fluid pressure supplied to the rapid advance cylinders, not shown, rises to a predetermined value such as occurs when the platen 3 initially is resisted by the work. Pressure switch PS-1 would then initiate the pump stroke position control for advancing the ram against the work.

The solenoid circuit also shows that the second switch means includes, besides limit switch LS-2, a pressure switch PS-2 operative in response to the fluid pressure to ram cylinder 5 attaining a predetermined high value to cause energization of relay K2 to change the control to pressure taper.

The solenoid control circuit also shows that a pressure switch PS-3 may be employed to operatively connect relay K3 in lieu of limit switch LS-3. In this event pressure switch PS-3 which is normally open at a high pressure in ram cylinder 5 would be operative to close when such pressure had reached a preset low value to change the control from pressure taper to ram position control, but would not be effective to energize relay K3 unless the contacts K2-10 of relay K2 were closed, thereby assuring the sequence operation of pressure taper before ram position control could be effected.

The solenoid control circuit, FIG. 3, also shows a relay K5 that is operatively available in lieu of relay K3 by manual operation of selector switch SS-1. Relay K5 has contacts K5-1 to establish its own holding circuit and contacts K5-2 to disconnect relay K2. Relay K5 is operative to change the control from pressure taper provided by relay K2 to pressure hold, whereas relay K3 provides for position hold.

Relay K5 has contacts K5-3 and K5-4 which are opened and closed, respectively, to maintain the secondary winding 95 of transformer 94 in the slideblock control circuit whose terminals 86, 87 remain shunted by contacts K1-2, K4-3. Thus amplifier 63 is provided with signal voltages from coupling transformer 94 and from slideblock position LVDT-1.

Relay K5 causes the control circuit to provide a pressure command signal via the preamplifier. Such pressure signal is provided by LVDT-3 and a preset signal from a pressure command potentiometer 88 whose input

terminals are connected to taps c and d of the supply transformer.

The output of pressure command potentiometer 88 is connected by contacts K5-5 in a closed loop series circuit with the pressure gain potentiometer 96 and the output winding of LVDT-3, which is reconnected to line d¹ by normally closed contacts K2-8 and is isolated from LVDT-2 by normally open contacts K2-7. The output terminals 98, 99 of the pressure gain potentiometer 96 remain connected to the input of the preamplifier 64. Therefore, the pressure error signal which is the difference of the signals of pressure command potentiometer 88 and pressure transmitter LVDT-3 is transmitted through the pressure gain potentiometer 96, the preamplifier 64 and the coupling transformer 94, to the slideblock control including amplifier 63. As a result, the pressure error signal causes the torque motor 61 to position the pump slideblock via the hydraulic control combination so that the pressure of fluid discharged by the pump will decrease, or increase if necessary, to the predetermined value called for by the command of potentiometer 88. The pump is thus controlled to vary its stroke as necessary to hold the discharge pressure at a constant value irrespective of the ram position.

The final work position of the press platen may thus be varied slightly so as to hold a final predetermined pressure on the work for a given interval of time as determined by the timing device T which is energized through contacts K5-9 of relay K5. The timing device after the given interval of time closes timing switch TS-1 as heretofore described for energizing relay K-4 to cause decompression of the ram cylinder, opening of the press, and return of the pump to neutral preparatory to removing the work and preparing for another press work cycle of operation.

While a single embodiment of the invention has been shown and described, some changes have been indicated in the switching means to initiate steps in the sequence of control, it should be obvious that other changes and modifications may be made without departing from the spirit of the invention or from the scope of the appended claims.

I claim:

1. A control system for a hydraulic press having a ram cylinder, a ram movable in said cylinder for actuating said press, a supply a motive fluid connected to said cylinder, signal means, electrohydraulic means operatively connected to said signal means for controlling said supply of motive fluid to said ram cylinder, said signal means comprising a position feedback signal transmitter operative to provide a signal in accordance with the displacement of said electrohydraulic means from a neutral position, a pressure transducer transmitter operative to provide a signal in accordance with the pressure of the motive fluid supplied to said ram cylinder, a ram position transmitter operative to provide a signal in accordance with the position of said ram, and first switch means operable to connect said pressure transducer transmitter and said ram position transmitter so that the difference of their signals command said electrohydraulic means in opposition to the signal of said position feedback signal transmitter so that the pressure of the fluid in said cylinder varies in accordance with the position of said ram.

2. A control system for a hydraulic press having a ram cylinder, a ram movable in said cylinder for actuating said press, a supply of motive fluid connected to said cylinder, signal means, electrohydraulic means operatively connected to said signal means for controlling said supply of motive fluid to said ram cylinder, said signal means comprising a position feedback signal transmitter operative to provide a signal in accordance with the displacement of said electrohydraulic means from a neutral position, a pressure transducer transmitter operative to provide a signal in accordance with the pressure of the motive fluid supplied to said ram cylinder, a ram posi-

tion transmitter operative to provide a signal in accordance with the position of said ram, first switch means operable to connect said pressure transducer transmitter and said ram position transmitter so that the difference of their signals commands said electrohydraulic means in opposition to the signal of said position feedback signal transmitter and second switch means operable in response to said ram attaining a predetermined position for operatively disconnecting one of said command signal transmitters and operatively connecting a predetermined command signal means and the other of said command signal transmitters to said electrohydraulic means in opposition to the signal of said position feedback transmitter; whereby said electrohydraulic means is operated to control said supply of motive fluid so as to hold a predetermined pressure on said ram or hold said ram at a predetermined position.

3. A control system for a hydraulic press comprising a working ram, a ram cylinder, a hydraulic pump connected to said cylinder, a variable displacement member for varying the stroke of said pump, a servovalve controlling the position of said displacement member, an electric motor controlling said servovalve, signal receiving means controlling the energization of said electric motor, a pump stroke signal transmitter operatively connected to said variable displacement member for producing a feedback signal which varies in accordance with the stroke of the pump, a ram position signal transmitter operatively connected to said ram so as to produce a signal varying with the position of said ram, a pressure signal transmitter operative to produce a signal varying with the pressure of fluid supplied to said ram cylinder, and switch means operatively connecting said signal transmitters to said signal receiving means to command said pump to vary its stroke so as to maintain a minimum difference between said signals of said ram position transmitter and said pressure transmitter, whereby the pressure applied to said ram is varied in accordance with its position during a working stroke of the ram.

4. A hydraulic press having a hydraulic cylinder and a ram reciprocable in said cylinder, a hydraulic pump connected to supply motive fluid to said cylinder and having a variable displacement member for varying the stroke of the pump, a servo motor controlled by a servovalve to position said displacement member, an electric motor coupled to said servo valve, a source of electric power, an electric amplifier operatively connecting said source of power to said electric motor and having signal input terminals for receiving a variable signal control voltage whose valve determines the output of said amplifier, a first signal means providing a voltage in accordance with the position of said displacement member and connected in series with said amplifier to cause return of said displacement member to a neutral position for a zero stroke of the pump, a switch means operable at a predetermined pressure of said fluid supplied to said ram, a second signal means providing a voltage in accordance with the pressure of said fluid supplied to said ram, a third signal means providing a voltage in accordance with the position of said ram, said switch means operatively connecting said second and third signal means so that the difference of their voltages is applied to said amplifier; and a second switch means operable upon said ram attaining a predetermined position, a command means providing a voltage, said second switch means operatively disconnecting said second signal means and connecting said command means and said third signal means so that the difference of their voltages is applied with said first signal means to said amplifier.

5. In a hydraulic press, a control system for controlling the working stroke of a hydraulic ram reciprocable in a cylinder, said system comprising a pump connected to said cylinder and having a displacement member for varying the stroke of the pump, a servo motor controlled by a servo valve to position said displacement member,

an electric motor coupled to said servo valve, signal receiving means controlling the energization of said electric motor in accordance with the value of signals received, a pump stroke signal transmitter operatively connected to said displacement member to produce a pump stroke signal varying in accordance with the stroke of the pump, said pump stroke signal transmitter operatively connected to said signal receiving means for urging said pump to zero stroke; a first switch means, a stroke command means providing a stroke command signal for a predetermined stroke of the pump, said first switch means operable to connect said stroke command means to said signal receiving means to urge said pump to said predetermined stroke to minimize the difference of said stroke command signal and said pump stroke signal; a pressure switch operable at a predetermined pressure of fluid supplied to the ram cylinder, a pressure signal transmitter operable to produce a pressure signal varying in accordance with the pressure of the fluid supplied to the ram cylinder, a ram position signal transmitter operatively connected to the ram to produce a ram position signal varying in accordance with the position of the ram, said pressure switch operatively connecting said pressure signal transmitter and said ram position transmitter to apply the difference of their signals to said signal receiving means, so that the stroke of the pump is varied to minimize the difference of said pressure signal and said ram position signal, whereby the pressure applied to said ram varies with the position of said ram; a ram position switch operable at a predetermined position of the ram, a ram position command signal means providing a signal for causing the ram to move to a predetermined command position, said ram position switch operatively disconnecting said pressure signal transmitter and operatively connecting said ram position command signal means and said ram position signal transmitter to apply the difference of their signals to said signal receiving means whereby said ram is urged to said predetermined command position to minimize the difference of said ram position signal and said ram position command signal.

6. In a hydraulic press, a control system for controlling the working stroke of a hydraulic ram reciprocable in a cylinder, said system comprising a pump connected to said cylinder and having a displacement member for varying the stroke of the pump, a servo motor controlled by a servo valve to position said displacement member, an electric motor coupled to said servo valve, signal receiving means controlling the energization of said electric motor in accordance with the value of signals received, a pump stroke signal transmitter operatively connected to said displacement member to produce a pump stroke signal varying in accordance with the stroke of the pump, said pump stroke signal transmitter operatively connected to said signal receiving means for urging said pump to zero stroke; a pressure switch operable at a predetermined high pressure of fluid supplied to the ram cylinder, a pressure signal transmitter operable to produce a pressure signal varying in accordance with the pressure of the fluid supplied to the ram cylinder, a ram position signal transmitter operatively connected to the ram to produce a ram position signal varying in accordance with the position of the ram, said pressure switch operatively connecting said pressure signal transmitter and said ram position transmitter to apply the difference of their signals to said signal receiving means so that the stroke of the pump is varied to minimize the difference of said pressure signal and said ram position signal, whereby the pressure applied to said ram varies with the position of said ram; a ram position switch means subsequently operable at a predetermined position of the ram, a pressure command signal means, said ram position switch means operatively disconnecting said ram position signal transmitter means and operatively connecting said pressure command signal means and said pressure signal transmitter means to apply the difference

11

of their signals to said signal receiving means for maintaining a predetermined low fluid pressure applied to said ram.

7. In a hydraulic press having a movable platen, a ram cylinder and a ram in said cylinder for moving said platen, a control system for controlling the working stroke of said ram to a predetermined closing position of the press, said control system comprising a variable displacement pump connected to supply fluid under pressure to said ram cylinder, said pump having a displacement varying member for varying the stroke of said pump, a hydraulic servo motor for moving said displacement member, a follow-up servovalve controlling a supply of control pressure fluid to said servo motor, an electric motor for positioning said servovalve, an electric amplifier controlling the energization of said electric motor in accordance with the value of signal voltages applied to signal input terminals of said amplifier, a source of control voltage, a pump LVDT having a primary winding energized by said source of control voltage and a secondary winding connected in series with said signal input terminals of said amplifier, said pump LVDT having a movable core member operatively connected to said pump displacement member to vary the voltage of its secondary winding in accordance with the position of said pump displacement member so as to cause said displacement member normally to move to a position to minimize said pump LVDT signal voltage; a first stroke command potentiometer connected to said source of control voltage, and switch means operable to connect output terminals of said first stroke command potentiometer in series with said output winding of said pump LVDT to command said pump to a predetermined stroke; a platen

12

position LVDT having a primary winding energized by said source of control voltage and a secondary winding, a movable core member operatively connected to said movable platen so as to vary the voltage on said secondary winding in accordance with the position of said platen, a pressure LVDT having a primary winding energized by said control voltage, a secondary winding, and a movable core member displaced in accordance with the pressure supplied to the ram cylinder so as to vary the voltage of its secondary winding in accordance with said pressure, and a pressure switch operatively disconnecting said first stroke command potentiometer and operatively connecting said secondary windings of said platen position LVDT and said pressure LVDT so as to apply the difference of their signal voltages to input terminals of a preamplifier, said pressure switch also operatively connecting output terminals of said preamplifier in series with said secondary winding of said pump LVDT and said signal input terminals of said amplifier, whereby the stroke of the pump is controlled to vary ram pressure with ram position; a ram position command potentiometer connected to said source of control voltage, a position switch means actuated upon said platen attaining a predetermined position for operatively disconnecting said pressure LVDT and operatively connecting output terminals of said ram position command potentiometer in series with the secondary winding of said platen position LVDT and said input terminals of said preamplifier so that its output commands said amplifier to cause the stroke of the pump to vary for moving said platen to another predetermined position and for holding said platen in said position.

No references cited.