Aug. 13, 1946. E. CANNON 2,405,640

APPARATUS FOR CONTROLLING THE SLIDE MOVEMENT IN LONG-BED HYDRAULIC PRESSES

Filed May 15, 1943 4 Sheets-Sheet 1

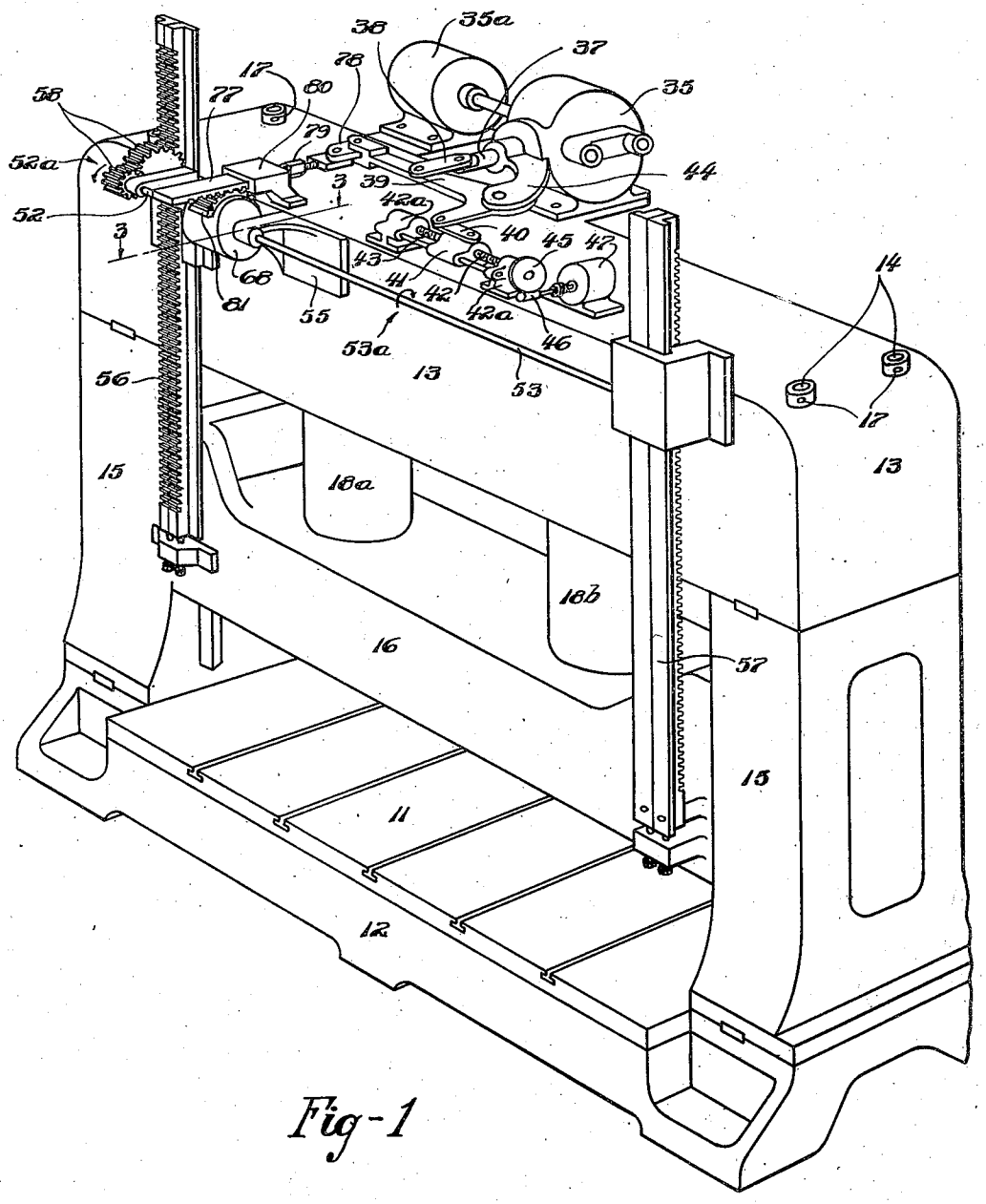


Fig-1

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Filed May 15, 1943 4 Sheets-Sheet 2

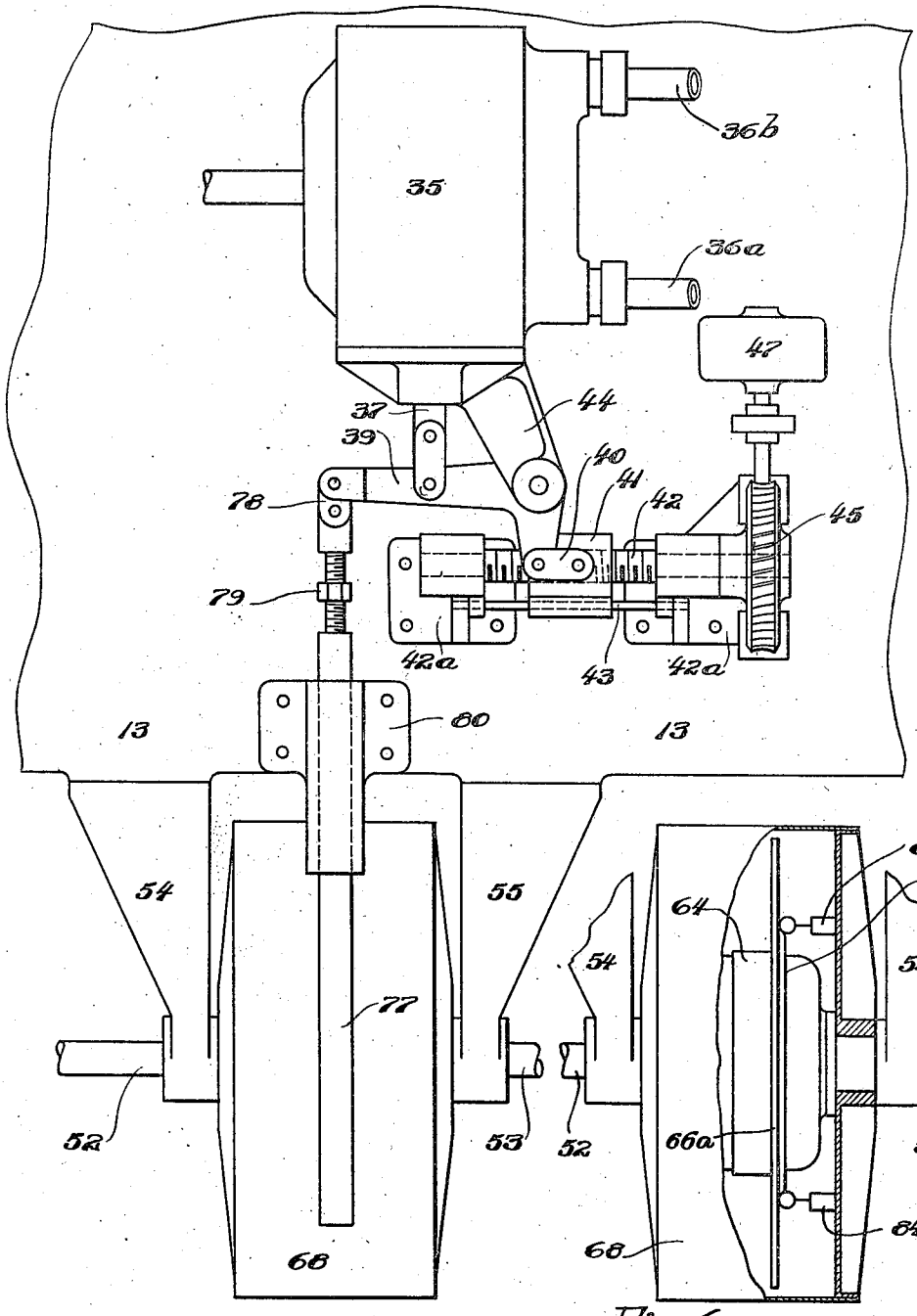


Fig-2

Fig-6

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Filed May 15, 1943 4 Sheets-Sheet 3

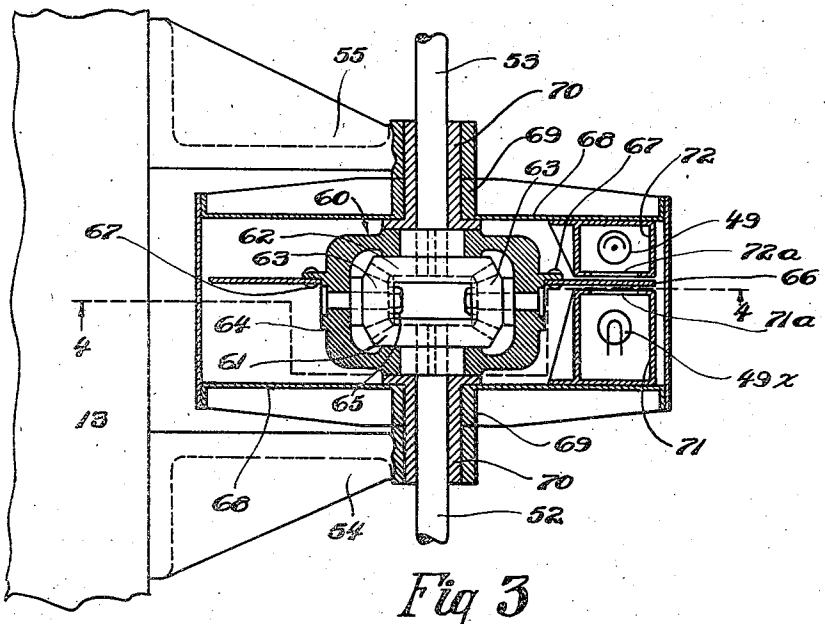


Fig 3

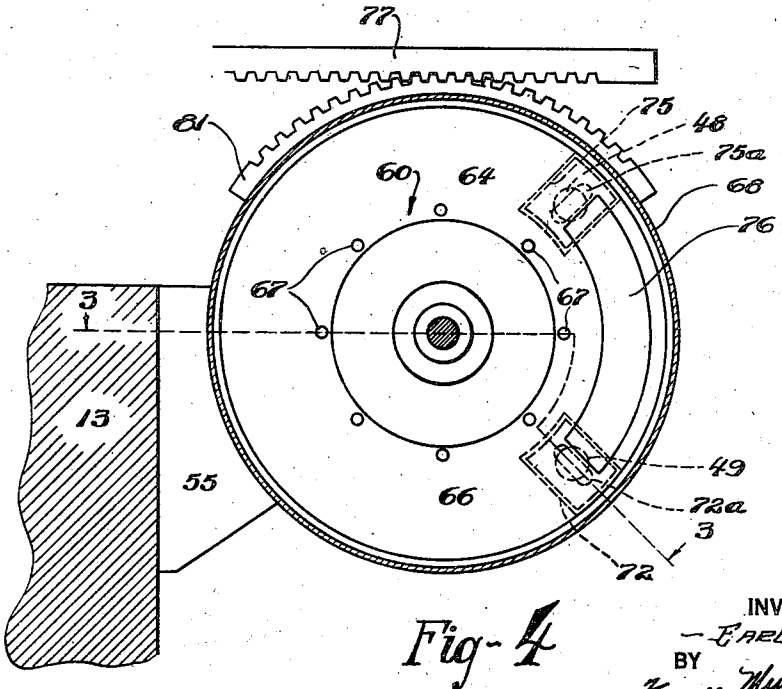


Fig- 4

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Filed May 15, 1943 4 Sheets-Sheet 4

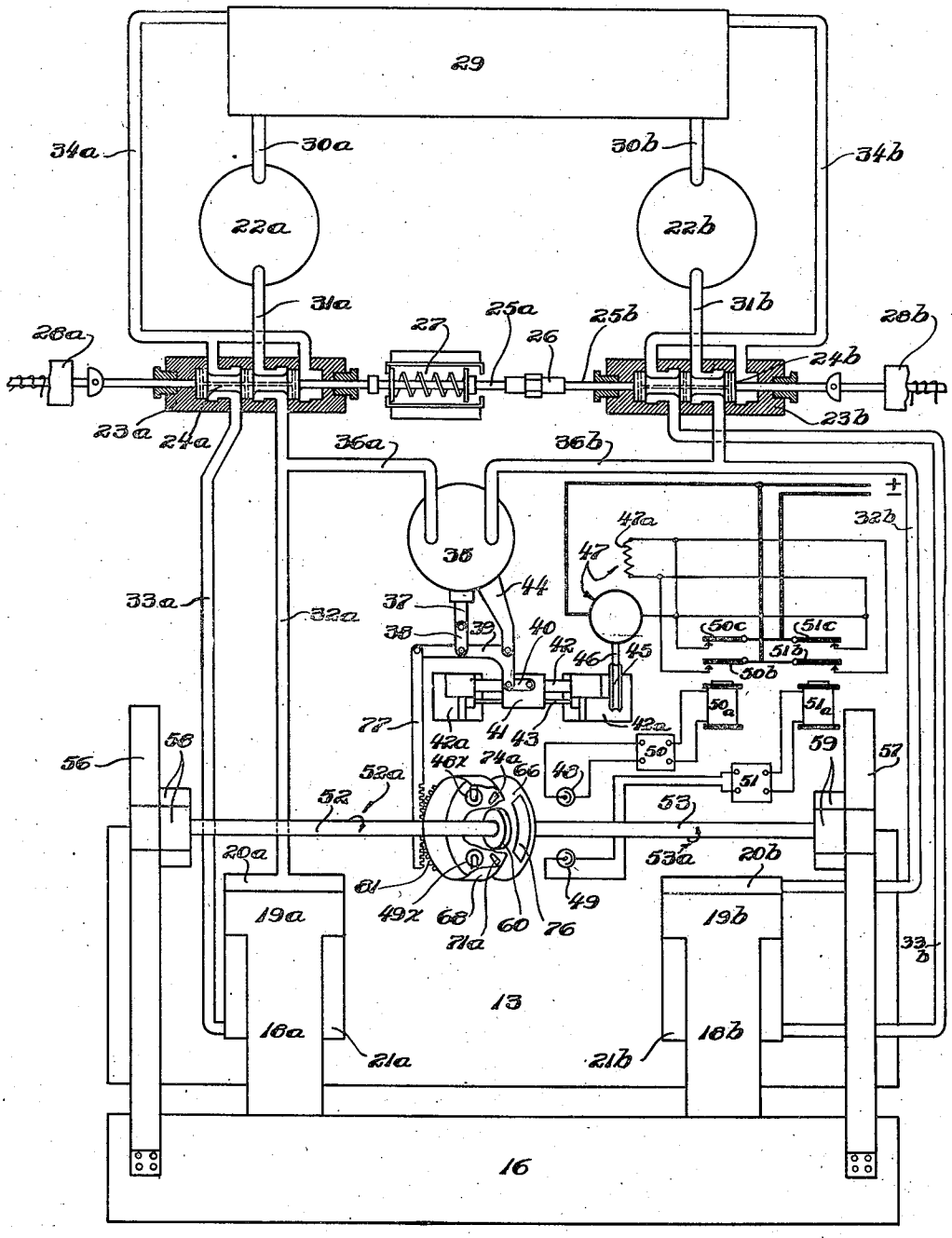


Fig-5

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Patented Aug. 13, 1946

2,405,640

UNITED STATES PATENT OFFICE

2,405,640

APPARATUS FOR CONTROLLING THE SLIDE MOVEMENT IN LONG-BED HYDRAULIC PRESSES

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Application May 15, 1943, Serial No. 487,106

25 Claims. (Cl. 100—71)

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This invention relates to improvements in apparatus for controlling the slide movement in long-bed hydraulic presses, and more particularly relates to self-modifying controlling means for maintaining the slide of such a press substantially in parallelism with the press bed during the advance or closing movement of said slide despite any die or blank irregularity which might tend to induce tilting of the slide.

Any reference in the following specification and claims to "parallelism" or "non-parallelism" is intended to relate to the attitude of the press slide relatively to the bed of a press. "Substantial parallelism" is intended to include a minor degree of non-parallelism which is within permissible practicable limits. The term "long-bed hydraulic press" refers to any hydraulic press wherein the present invention may be employed advantageously to maintain such substantial parallelism.

In my co-pending Patents 2,353,388 and 2,353,389, issued July 11, 1944, there are disclosed electrical means, for maintaining substantial parallelism of a slide of a long-bed press, wherein control is exerted to effect compensation in the volumes of liquid delivered to ram advance chambers toward opposite sides of a long-bed press. In the embodiments illustrated in the said copending patents, only two different stages or degrees of compensation are provided. This arrangement usually affords somewhat more or less than the precise compensation required in a particular case, and, hence, the compensating effect may be intermittent during the down stroke of the press slide, thereby causing the press slide to pursue a rocking motion during its advance movement, all as may be understood from the said patents.

There are distinct advantages in employing electrical means to achieve such compensation in the delivery of fluid to advance chambers at opposite sides of a press slide, and in most cases it would be highly desirable to fully or at least substantially eliminate the mentioned rocking motion.

An important object of the present invention is to provide electrical compensating means which may yield compensation in the volumes of liquid supplied to ram advance chambers toward opposite sides of a hydraulic press slide to an extent which will cause the slide to pursue its advance movement in a substantially unchanging and substantially parallel attitude with respect to the press bed.

Another important object of the invention is

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the provision of electrical compensating means which are initially rendered effective to commence compensation in the volumes of liquid supplied to several such advance chambers in response to a slight departure of the press slide from parallelism and to give to such controlling means a self-modifying effect, rendering the compensating means effective only to the extent necessary to offset the effect of the forces tending to upset the parallelism of the press slide, so that rocking of the latter during its advance stroke may be obviated or minimized.

A further object is to provide a self-modifying compensating arrangement, of the character mentioned in the preceding paragraph, which is simple and highly sensitive, both in responding to non-parallelism of the press slide in commencing its compensating effect and in limiting the degree of compensation to that which will cause the press slide to advance with little or no rocking effect.

The foregoing and other objects are achieved according to the present invention by providing a compensating pumping mechanism which may be automatically adjusted to vary the relative volumes of liquid pumped to ram advance chambers toward opposite sides of a press slide; controlling means responsive to non-parallelism of the press slide and adapted to initiate a change in the adjustment of the said pumping mechanism to cause the latter to effect a compensating variation in the delivery of liquid to said chambers; and control-modifying means coacting with said controlling means to limit the adjustment thereof to that adjustment under which the press slide will be caused to continue its advance movement with little or no rocking movement.

More specifically, I provide a continuously-acting, reversible, variable delivery compensator pump arranged so that it may increase the volume of liquid supplied to one ram advance chamber relatively to the volume of liquid supplied to the other; two photoelectric cells or switches arranged so that one or the other becomes activated or closed upon even a slight departure of the press slide from parallelism; a reversible electric motor, controlled by said cells or switches and adapted to reversibly vary the control of said pump; and a mechanism actuated by the said reversible electric motor, which mechanisms, after the proper pump adjustment is attained yielding uniform advance movement of the press slide, is adapted to close off light from and thus de-activate the mentioned activated cells, or to open said switches whereby to stop said motor and thus

terminate the variation in the compensator pump adjustment at the proper point to derive continued compensation which will enable the press slide to continue its advance movement in substantial parallelism.

For the purpose of illustrating the present invention, and without limiting the invention thereto, several preferred embodiments are shown in the accompanying drawings, in which:

Figure 1 is a perspective view illustrating the application of either mentioned embodiment of the present invention to a long-bed press;

Fig. 2 is a fragmentary top plan view of the press and certain portions of the apparatus shown in Fig. 1;

Fig. 3 is a sectional view of apparatus comprising a first embodiment of the invention, taken substantially on the lines 3—3 of Figs. 1 and 4 and illustrating the use of photoelectric cell assemblies;

Fig. 4 is a vertical sectional view taken substantially on the line 4—4 of Fig. 3;

Fig. 5 is a diagram illustrating the various component parts of said first embodiment of the invention and the interconnection of said parts; and

Fig. 6 is a fragmentary elevation, partly broken away, looking down on certain important parts of a second embodiment including limit switches which may be employed instead of the photoelectric cells illustrated in the first mentioned embodiment of the invention.

General structure of press with which the invention is illustrated

Referring, first, to Fig. 1: The press with which the invention is illustrated may comprise a long-bed **11** provided in a base **12** suitably tied at its opposite ends to a crown **13** by tie-rods **14** extending through slide housings **15** which serve, at least partially, to guide a vertically reciprocating slide **16**, and to suitably space apart the said crown and bed and to maintain the two latter members fixedly in their proper relationship. Tie-rod nuts **17** preferably are provided at the upper and lower ends (the latter are not visible in the drawings) of the said tie-rods.

The slide **16** is reciprocated in a well-understood manner by rams **18***a*, **18***b*, fixed symmetrically upon the slide toward opposite ends thereof. These rams, as best understood from Fig. 5, may be enlarged at their upper ends to form ram pistons **19***a*, **19***b*, and may be urged downwardly on their advance strokes by liquid introduced into advance chambers **20***a*, **20***b*, and upwardly on their return strokes by liquid introduced into return chambers **21***a*, **21***b*. The said chambers, of the general character indicated in Fig. 5, may, of course, be suitably formed within the crown **13** of the press.

Separate, substantially identical, pumping systems are provided for handling the supply of liquid for operating each of the rams **18***a* and **18***b*. These pumping systems function alike, and comprise suitably driven pumps **22***a*, **22***b*, and slide valves **23***a*, **23***b*, which are constrained to function in unison by having their pistons **24***a*, **24***b* tied together by rods **25***a*, **25***b*, and turnbuckle **26**. The said pistons may be held normally in their mid-positions by a well-understood spring-centering device **27**, and may be urged to the left and right, respectively, by solenoids **28***a*, **28***b*, which are connected in suitable electric circuits adapted to control the closing and opening of the press.

The said pumps draw liquid from a tank **29** through pipes **30***a*, **30***b*, and discharge liquid through pipes **31***a*, **31***b*, and through the valves **23***a*, **23***b*, either into the ram advance chambers **20***a* and **20***b*, which are, respectively, served by pipe lines **32***a*, **32***b*, to effect an advance or closing movement of the press slide, or into return chambers **21***a* and **21***b*, which are, respectively, served by pipe lines **33***a*, **33***b*, to achieve the return or opening movement of the press slide. The direction of stroke of the press, of course, depends on whether the valve pistons are in their left position, as shown in the drawings, to achieve the advance movement, or in their right position to achieve the return movement. If the said pistons are in their mid-positions, the liquid charged into the valves **23***a*, **23***b*, instead of being pumped to the ram chambers, passes through interior passages (indicated in broken lines) in said pistons, whence it returns to the tank through pipe lines **34***a*, **34***b*.

Although the pumping systems for operating the rams **18***a*, **18***b*, may be substantially identical in design, it will be appreciated that, where resistance to the advance of the slide is not uniformly distributed thereover, the different slippages in the two pumps, slight leakages, and possibly other factors, may cause the side or end of the press slide encountering the least resistance to advance ahead of the other side thereof, and this uneven advance or cocking of the slide in many instances may become more pronounced as the slide progresses toward the end of its advance stroke. This highly undesirable cocking of the press slide may be substantially obviated by compensating means now to be described in detail.

The compensating pumping mechanism

According to the present invention, it is preferred to provide a compensator pump **35** which may be connected in various ways to achieve the effects of the operation hereinafter set forth. In the disclosed embodiment, the said pump is connected by a pipe **36***a* to the pipe **32***a* which carries the liquid supply to ram advance chamber **20***a*, and is connected by a pipe **36***b* to the pipe **32***b* which carries the liquid supply to ram advance chamber **20***b*.

The compensator pump **35**, if connected in the manner just described, preferably should be a continuously-acting reversible pump, suitably driven as by an electric motor **35***a*. The pumping mechanism of said compensator pump, further, is preferably adjustable by movable means which extend to the exterior of the pump itself for reversing the flow of liquid through the pump and for controlling the volume of such flow. Although various types of pumps having pumping mechanisms conforming to these preferred characteristics may be used, a pump of the so-called "Hele-Shaw" type, such as is illustrated and described in my Patent 2,328,258, issued August 31, 1943, is well suited to the purpose of the present invention.

Adjustment of flow through the compensator pump

As the particular pumping mechanism employed in the compensator pump is not an essential part of the present invention, the said pump is not described herein in detail. It is sufficient to observe for present purposes that the flow of liquid through the pump **35** may be reversed, and the volume thereof controlled, by a reciprocating control member **37** which extends from the interior mechanism of said pump to the exterior

thereof and yields volume control substantially proportionate to the extent of its movement. The control member 37 is operatively connected through a link 38, a bell-crank 39, and a link 40 to a traveling nut 41 which is threaded upon and adapted to travel along a suitably mounted screw 42 when the latter is rotated. The nut 41 is restrained against rotation by a fixed guide rod 43 which extends through a suitable bore in said nut and is retained, at its ends, in supports 42*a* which carry bearings accommodating the ends of the screw 42. The several mentioned connections between the control member 37 and the nut 41 are all pivotal connections, and the bell-crank is fulcrumed upon a bracket 44 which may be mounted upon the body of the compensator pump 35. The screw 42 is constrained to turn with a worm-wheel 45 keyed thereto, and the worm-wheel is driven by a worm 46 suitably coupled to and driven by a reversible, electric, pilot motor 47.

A dual control is provided for operating the electric motor 47; first, a control which starts the said motor in either direction, in order to initiate the adjusting movement of the control member 37, as soon as the press slide departs even slightly from parallelism and, second, a control which stops said motor as soon as the control member 37 is moved sufficiently to yield an adjustment of the compensator pump 35, which causes the latter to establish and maintain a compensating effect which will cause the press slide to advance uniformly and without substantial rocking motion.

Initiation of adjustment of the compensator pump

The said first control as employed in the illustrated first embodiment, comprises two similar electric circuits, one for control of the motor 47 in each direction. Although the motor 47 may be any one of various suitable types, it is diagrammatically illustrated in Fig. 5 as having a shunt winding 47*a* which may be in the stator of the motor. The mentioned circuits include photoelectric cells 48, 49, which are respectively arranged in circuits of suitable amplifiers 50, 51, the latter, respectively, being connected separately to the coils of relays 50*a*, 51*a*. These relays, through their normally open contactors 50*b*, 50*c*, 51*b*, 51*c*, control the flow and direction of flow of current through the winding 47*a* from the two leads, indicated by a plus and a minus sign, comprising a source of electric energy. Contactors 50*c*, 51*c*, also control unidirectional current flow through the rotor of the motor 47.

Means for controlling the passage of light to the mentioned photoelectric cells are shown in detail in Figs. 3 and 4 and in diagrammatic form in Fig. 5. The relationship of said means to the operating parts of the press may best be understood from Figs. 1 and 2, from which it may be seen that horizontal cross-shafts 52, 53, carried respectively at their inner ends in bearing brackets 54, 55, mounted upon the crown 13 and also by suitable bearing brackets located near their outer ends are arranged to be rotated in opposite directions by oppositely-facing, vertically-extending racks 56, 57, which are secured at their lower ends to opposite sides of the slide 16. These racks, of course, move vertically with the said slide and turn the shafts 52, 53, through step-up gear train 58 visible at the left side of the press in Fig. 1 and a somewhat similar but oppositely-acting gear train 59 as indicated diagrammatically in Fig. 5.

A differential mechanism 60 which may be of a conventional type is employed between the shafts 52 and 53, as shown in Fig. 3. As illustrated, it comprises bevel gears 61 and 62 keyed respectively upon the inner ends of shafts 52 and 53 and meshing with bevel differential gears 63 which are mounted within a cage 64 upon studs 65. The cage 64, preferably, is so mounted upon suitable bearings as to be capable of turning about the common axis of the shafts 52 and 53.

It should be apparent that if the parallelism of the press slide 16 is maintained as it descends, the shafts 52 and 53 move in similar degrees but in opposite directions, so that the rotation imparted to the differential gears 63 by the bevel gear 61 tending to turn the cage 64 in one direction is exactly counteracted by the rotation imparted by the bevel gear 62 to said differential gears tending to turn said cage in the opposite direction. Hence, it results that while the slide 16 moves downwardly in parallelism with the bed 11 the cage 64 remains at rest.

On the other hand, if the parallelism of the slide 16 is not maintained as it moves downwardly, one of the shafts 52, 53 turns to a greater degree than the other, thus, through the differential gears 63 imparting a rotative movement to the cage 64 in a direction and to an extent which depends upon the direction and extent of tilting of the press slide.

A movable shutter member, which may be in the form of an opaque disc 66, is fixed upon the cage 64 by any suitable means as, for example, by bolts or rivets 67, so that said disc is rotated with said cage in response to any departure of the press slide from parallelism. The differential mechanism and the disc 66 preferably are enclosed within a drum-like casing 68 having hubs 69, which turn upon bearing members 70 in the form of bushings which extend about the shafts 52, 53 and are supported by the brackets 54, 55.

There preferably are provided, within the casing 68, two similar photoelectric cell assemblies including related light sources, one of which assemblies is adapted to control a circuit operating the motor 47 in one direction and the other of which is adapted to control a circuit operating said motor in the other direction. In Fig. 3, there is disclosed only one of said assemblies, located below the central horizontal plane of the casing 68. Said assembly comprises a light source in the form of an incandescent lamp 49*x* and the photoelectric cell 49, which, preferably, are mounted respectively within separate compartments 71, 72 fixed inside the casing 68. The adjacent walls of said compartments are respectively provided with aligned radial slots 71*a*, 72*a*, adapted to permit passage of light rays from the lamp 49*x* to the cell 49. The compartment 72, the slot 72*a*, and the cell 49 of the assembly are indicated in broken lines in Fig. 4.

The other of said cell assemblies, located above the central horizontal plane of the casing 68, may be similar in all respects to the assembly described in detail in the next preceding paragraph. In Fig. 4, the cell 48 in said other assembly, the said cell's compartment 75, and the latter's radial slot 75*a* are indicated in broken lines, thus making clear the relative radial positions of the two mentioned cell assemblies within the casing 68.

As best seen in Fig. 4, the opaque disc 66 is provided with an arcuate concentric opening 76 which is of such length that its ends, in what may be termed a neutral position of said disc with respect to the casing 68, may extend to points

only minutely out of register with the slots in the two said assemblies so that with the said disc in such neutral position no light may pass from the several incandescent lamps to the corresponding photoelectric cells.

Operation of means initiating adjustment of the compensator pump

It will be seen that, with this arrangement, a slight non-uniformity in the advance movement of the press slide will rotate the cage **64** and the disc **66** carried thereby to some extent, thus causing the arcuate opening **76** to at least partly register with the radial slots in one or the other of the mentioned cell assemblies to permit the passage of light to and cause the activation of one or the other of the cells **48, 49**, depending upon the direction of cocking of the press slide.

The activation of one or the other of said cells completes a circuit through the related amplifier **50** or **51** and related relay coil **50***a* and **51***a* in a well understood manner. It may be seen from Fig. 5, that the connections between the plus and minus leads, comprising the source of current supply, and the shunt winding **47***a* and rotor of the motor **47** are established through the contactors of the relay coils **50***a* or **51***a* and are so arranged that when coil **50***a* is energized through the activation of cell **48**, the current passes through the winding **47***a* in one direction and when coil **51***a* is energized through the activation of cell **49**, the current passes through said winding in the opposite direction, the current flow through the rotor being unidirectional. Thus, the motor **47** may be controlled to operate in the proper direction to initiate movement of the pump control member **37** to cause the pump **35** to pump liquid from the liquid supply of the ram chamber at the faster moving side of the press slide to the liquid supply of the ram chamber at the slower moving side of the slide, to substantially equalize the volumes of liquid being pumped into the two said chambers in order to prevent further increment in non-parallelism despite non-uniformity in distribution of the forces resisting the advance of the slide. The connections of the cells **48** and **49** in the circuits controlling the motor **47** are, of course, so arranged that the operation of the said motor will be in the proper direction to initiate such equalization.

Limitation of adjustment of the compensator pump

A second control, which terminates the operation of the motor **47**, comprises a rack **77** which is preferably connected through a link **78** and a turnbuckle connection **79** to the arm of the bellcrank **39** which actuates the pump control member **37**. The said rack is preferably guided by a guide member **80** which may be fixed upon the crown **13** of the press. The toothed portion of said rack is arranged to engage a toothed segment **81** integrally formed with or fixed upon the periphery of the drum **68**.

This second control functions to terminate the operation of the motor **47** by reason of the fact that, as the operation of said motor modifies the adjustment of the compensator pump **35** it also actuates the rack **77** which turns the drum **68** in the same direction as the disc **66** had previously turned to start said motor. Thus, as the adjustment of the pump **35** brings the compensating action of the pump up to the point at which the discharge of liquid to the two ram advance chambers is substantially equalized, the rotation of the drum **68** progresses to the point where the slots in both photoelectric cell assemblies are in neutral or non-registering positions relatively to the arcuate opening **76** in the disc **66**.

When the mentioned non-registering relationship is reached the photoelectric cell which had previously been activated to start the motor **47** becomes deactivated, and the other photoelectric cell remains deactivated so that the adjustment thus established in the operation of the pump **35** remains effective and the three pumps **22***a*, **22***b* and **35** function together to deliver uniform quantities of liquid to the ram chambers **20***a* and **20***b* in order to accomplish the advance stroke of the press slide without permitting more than a permissible departure of said slide from absolute parallelism.

In order to simplify Figure 5, the compartments **72, 75**, housing the cells **48, 49**, are not shown therein. The said figure, however, adequately indicates the relative positions of the essential parts of the several cell assemblies and of the shutter arrangement whereby to render the operation of the mechanism understandable. The lamps **48***x* and **49***x*, of course, are connected (in a manner not shown) to suitable sources of electric energy.

Complete operation of press and the slide movement control means

Although the operation of portions of the disclosed apparatus may be understood from the foregoing description, it should be helpful to review the operation of the press and its controlling means in its entirety. Referring particularly to Fig. 5, it may be assumed that the press is open and that the pistons **24***a*, **24***b*, the centering device **27**, and the related solenoids **28***a*, **28***b*, are in central or neutral positions, and that all other parts are in the positions indicated in said figure, the motor **47** being inactive and the pump **35**, although being continuously driven by its motor **35***a*, being in neutral adjustment under which no liquid is passing through said pump between the pipes **32***a* and **32***b*. It may be assumed, also, that the die or dies in the press are of such irregularity as to present a greater resistance to the advance of ram **18***b* than ram **18***a* so that when a blank in the press is engaged between dies or pressing members carried upon the bed **11** of the press and upon the press slide **16**, the left side of the slide **16** will tend to move downwardly in advance of the right side thereof.

The press operator, to start a cycle of operation, may close an electric circuit through solenoid **28***a*, causing the latter, upon thus being energized, to shift the valve pistons **24***a*, **24***b*, in unison, to the left to the positions shown in Fig. 5, thus permitting liquid from the tank **29** to be pumped by the pumps **22***a*, **22***b*, through the valves **23***a*, **23***b*, into ram advance chambers **20***a*, **20***b*, to move the rams **18***a*, **18***b*, downwardly; the liquid in return chambers **21***a*, **21***b*, meanwhile, being exhausted through pipes **33***a*, **33***b*, and through valves **23***a*, **23***b* and pipes **34***a*, **34***b*, into the tank **29**.

When the slide **16** reaches a point in its downward movement at which it is opposed by the engagement of the blank between the dies or pressing members, the greater resistance offered to the further advance of the right side of the slide causes liquid slippage in the pump **22***b*, or other conditions under which the ram chamber **20***b* receives a somewhat smaller volume of liquid than is received by ram chamber **20***a*, so that the left side of the press slide moves downwardly in ad-

vance of the right side thereof; and, unless the mentioned inequality of liquid delivery is remedied, the cocking of the slide becomes progressively greater and highly objectionable and possibly dangerous.

According to the present invention, however, at the very inception of such cocking of the press slide, the rotation of the shaft **52**, driven by rack **56** in the direction indicated by the arrow **52***a*, becomes more pronounced or of a greater degree than the opposite rotation (arrow **53***a*) of the shaft **53**, which is driven by the rack **57**. In the manner already explained, this difference of rotation of the two said shafts immediately causes the differential cage **64**, and the disc **66** carried thereby, to turn somewhat, in a clockwise direction as viewed in Fig. 4. As the relationship of the slot **72***a* to the arcuate opening **76** preferably is such that even a slight clockwise turning of the disc **66** will bring said slot and opening into at least partial register, it will be seen that as soon as cocking of the press slide commences, the turning of the disc **66** permits light rays to pass from lamp **49***x*, through slot **71***a*, arcuate opening **76**, and slot **72***a* to the cell **49**. Thus the latter is activated, thereby closing an electric circuit through related amplifier **51** and relay coil **51***a* to close contactors **51***b*, **51***c* and establish a circuit through winding **47***a* and the rotor of motor **47**, causing the latter to start operation, practically upon inception of non-parallelism of the press slide.

The motor **47**, upon closing of the mentioned circuit through winding **47***a*, operates in the direction which causes the worm-wheel **45** and the presumably "right" threaded screw **42** to turn in a clockwise direction, as viewed in Fig. 1, thereby causing the nut **41** to move along said screw toward the right and consequently causing the bell-crank **39** to move the pump control member **37** outwardly; and the mechanism of the pump **35** and the hydraulic connections thereof are such that the mentioned shifting of the control member **37** causes the said pump to transfer liquid from the pipe **32***a* to the pipe **32***b*.

The purpose of this transfer of liquid is to compensate for the differences of liquid volumes which the pumps **22***a*, **22***b*, deliver to the chambers **20***a*, **20***b*, as a result of the uneven distribution of resistance to the advance of the press slide. If opposite cocking of the slide occurs, compensation, opposite to that just described, is similarly initiated by the cell **48** and related amplifier **50** and relay coil **50***a* and contactors **50***b*, **50***c*, which pass current through the winding **47***a* in the direction opposite to that just described to yield opposite operation of the motor **47** and opposite operation of the compensator pump **35**. The cell **48** is activated by light which may pass thereto from lamp **48***x*, through slot **74***a*, arcuate opening **76**, and slot **75***a*.

Obviously, if the operation of the motor **47** were not discontinued at the proper time, the mentioned adjustment of the pump **35** would become too great, thus causing over-compensation which would result in the slide cocking in the opposite direction, whereupon similar but oppositely-acting controls of the cells **48** and **49**, functioning alternately, would cause the slide to advance with a rocking motion which the present invention seeks to avoid.

According to the present invention, however, the operation of the motor **47** may be discontinued at the proper time to leave the adjustment of the compensator pump **35** such that, thereafter, during the advance stroke of the press slide, the said pump substantially equalizes the volume of liquid effectively being delivered to the two ram advance chambers.

The mentioned stopping of the motor **47** occurs by reason of the fact that, as the bell-crank **39** turns, to move the control member **37** outwardly, it also operates the rack **77** which turns the casing **68** in the same direction (clockwisely, as viewed in Fig. 4) as the disc **66** previously turned in response to the departure of the press slide from parallelism; thus moving slots **71***a* and **72***a* into non-registering positions relatively to the arcuate opening **76**, whereupon the cell **49** becomes deactivated, opening the circuit through motor **47** and thereby stopping the latter.

Assuming proper design of the various components of the described apparatus, the motor **47**, after initiating adjustment of said pump, will stop at the time the said adjustment becomes effective to cause said pump to yield substantial equalization of the volumes of liquid being delivered to the two ram advance chambers.

Inasmuch as the motor **47** starts immediately upon even a slight departure of the press slide from parallelism, the pump **35** immediately commences to bring the volumes of liquid effectively delivered to the two ram chambers nearer to uniformity. After such uniformity is reached, the one of the cells **48**, **49**, which had previously been activated, becomes deactivated and both cells then remain deactivated; also the adjustment of the pump **35** remains in condition to maintain proper compensation unless further and different distribution of the resistance of the press slide occurs during the remainder of the advance stroke of the press slide.

If such further change in the distribution of the resistance occurs, the resulting non-parallelism again turns the disc **66** to activate whichever of cells **48**, **49** will set in motion the described means to again substantially equalize the volumes of liquid being delivered to the two ram advance chambers.

In well designed apparatus, the automatic adjustment of the pump **35** is completed before the slide departs beyond permissible limits of non-parallelism and the subsequent uniformity of rate of effective delivery of liquid to the two ram chambers causes the slide to continue its advance movement with little or no rocking motion while at all times remaining within permissible limits of non-parallelism.

Upon completion of the advance stroke of the press slide, the solenoid **28***a* is deenergized and the solenoid **28***b* is energized by any suitable manual or automatic electric circuit control arrangement, thereby shifting the pistons of valves **23***a*, **23***b* to their extreme "right" positions, as a result of which liquid is pumped through said valves to the ram return chambers **21***a*, **21***b* to yield the return stroke of the press slide, the liquid in chambers **20***a*, **20***b*, meanwhile, being exhausted through said valves and pipes **34***a*, **34***b*, to the tank **29**.

The lamps **48***x*, **49***x*, preferably, are so connected, in electric circuits (not shown), that they remain lighted at all times during the operation of the press. In the absence of some substantial non-uniform resistance the latter may maintain its slight permissible non-parallelism during the return stroke of the press slide because of the equality in the volumes of liquid being pumped into chambers **21***a*, **21***b* and because of the fact that the liquid passing through pump **35** courses

freely from the tank 29, through the valves 23a, 23b, and back to said tank.

If it is desired to stop the press when the return stroke is completed, the solenoid 28b is de-energized and the centering device 27 moves the pistons of valves 23a, 23b to their mid-positions to cut off the discharge of the pumps 22a, 22b, from any hydraulic connection with the several ram advance and return chambers in the manner already explained. Immediately thereafter, the transfer of liquid by the pump 35 from the left to the right side of the press operates to lower the ram 18b relatively to ram 18a thus restoring the parallelism of the slide.

While this restoration is taking place there occurs a reverse or counterclockwise rotation of the disc 66, activating cell 48 to cause reverse operation of the motor 47 which, as a result, shifts the pump control member 37 toward non-pumping adjustment. Meanwhile, the casing 68, again actuated through the medium of the rack 77, rotates counterclockwisely in a follow-up motion relatively to the disc 66 which brings the two into neutral relative positions, causing the motor 47 to stop and leaving the press slide in substantial parallelism, in readiness for a following similar cycle of operation.

If the press is so controlled as to start a further advance stroke, automatically, upon the termination of the return stroke, the mentioned restoration of the parallelism of the slide would ordinarily occur in the manner just described, during the initial or non-pressing part of the succeeding advance stroke. If under either the mentioned non-automatic or the automatic type of press operation, the said restoration to parallelism is not effected before the pressing part of the advance stroke begins, the unequal resistance to the advance movement, in any event, sets in motion the compensating mechanism in the manner already described.

As the cells 48 and 49 become activated in response to the rotation of the disc 66 in opposite directions and as the said cells yield opposite operation of the motor 47 and the casing 68, it is obvious that the described apparatus will yield compensation opposite to that herein described, where required by operating conditions.

The second embodiment

The illustrated second embodiment, shown in Fig. 6, differs from the first embodiment only in that the disc 66a, instead of having the arcuate opening 76, has a raised arcuate cam surface 82 which may be of the same shape as said opening, and that, instead of the two photoelectric cell assemblies, there are provided two limit switches 83, 84, which may be directly connected, respectively, in the circuits of the relays 50a, 51a, controlling the motor 47. Those familiar with the art will understand that this embodiment will function similarly to the described first embodiment.

The foregoing description sets forth preferred embodiments of this invention and a preferred mode of operation of the apparatus constituting the invention. While the design of the component parts of the apparatus should preferably yield the described mode of operation, nevertheless, it should be apparent that differences in design of parts or differences in conditions, as where complex and varying non-uniform resistances to the slide advance are encountered, may cause the invention to yield a somewhat different compensating operation than described. It should be understood that the stated description of operation is given primarily to aid in giving a full understanding of the invention and that the present invention is not limited to apparatus which necessarily operates in the precise manner described.

One advantage of the invention resides in the use of electric controls wherein positive electric connections rather than brush connections may be employed inasmuch as the limited range of rotation of the casing 68 makes it possible to utilize flexible connections to the several incandescent lamps and cells or to the several mentioned limit switches. Another advantage is found in the fact that there is no appreciable load imposed upon the racks 56, 57 and the several related gear trains, so that no material lost motion or backlash is encountered which would delay the action of the disc 66. The latter, in consequence, yields immediate control over the several photoelectric cells or limit switches and a resulting immediate initiation of the operation of the pump compensating means. Another of many advantages derivable from well designed apparatus according to the invention is the substantial elimination of any rocking motion during the pressing portion of the advance stroke of the press, although the invention is of such breadth as to include structures in which, for one reason or another, such rocking may occur.

In any event it is clear that the concept disclosed herein may be practiced in numerous forms without departing from the invention as defined in the accompanying claims.

What I claim is:

1. Apparatus for controlling the slide movement in a long-bed hydraulic press having slide-actuating rams and related ram advance chambers disposed toward opposite sides of the press slide and means for pumping liquid to said chambers, the said apparatus comprising adjustable compensating means for effecting compensating variations in the volumes of liquid pumped into said chambers, actuating means for varying the adjustment of said compensating means, and control means having two coacting, separately movable portions for controlling said actuating means; one of said movable portions being adapted to move in response to variations in the attitude of the press slide to initiate operation of said actuating means, and the other of said movable portions being adapted to move in response to variations in the adjustment of said compensating means to limit the operation of said actuating means.

2. Apparatus for controlling the slide movement in a long-bed hydraulic press having slide-actuating rams and related ram advance chambers disposed toward opposite sides of the press slide and means for pumping liquid to said chambers, the said apparatus comprising adjustable compensating pumping means for effecting compensating variations in the volumes of liquid pumped into said chambers, a reversible motor for varying the adjustment of said compensating means, and control means having two interacting, separately movable members for controlling said motor, one of said members being adapted to move in response to variations in the attitude of the press slide whereby to start said motor to initiate a variation in the adjustment of said compensating means, and the other of said members being adapted to move in response to variations in the adjustment of said compensating means

whereby to stop said motor to terminate the variation in such adjustment.

3. Apparatus for controlling the slide movement in a long-bed hydraulic press having slide-actuating rams and related ram advance chambers disposed toward opposite sides of the press slide and means for pumping liquid to said chambers, the said apparatus comprising adjustable compensating pumping means for effecting compensating variations in the volumes of liquid pumped into said chambers, a reversible electric motor for varying the adjustment of said compensating means, and control means having two interacting, separately movable members for controlling oppositely acting electric circuits through said motor, a first one of said members being adapted to move, in response to variations in the attitude of the press slide, in either of opposite directions depending upon the direction of such a variation, whereby to start said motor to initiate a compensation-yielding variation in the adjustment of said compensating means, and the other of said members being adapted to move, subsequently to and in the same direction as the movement of the first one of said members, in response to said adjustment variation, whereby to stop said motor to terminate the variation in such adjustment.

4. Apparatus for controlling the slide movement in a long-bed hydraulic press having slide-actuating rams and related ram advance chambers disposed toward opposite sides of the press slide and means for pumping liquid to said chambers, the said apparatus comprising adjustable compensating pumping means for effecting compensating variations in the volumes of liquid pumped into said chambers, a reversible electric motor for varying the adjustment of said compensating means, and control means comprising two electric circuits, adapted to control operation of said motor in opposite directions, a make and break device in each of said circuits, means, responsive to variations in the attitude of the press slide, for starting said motor, through establishment of a circuit in one of said devices, to initiate a compensation-yielding variation in the adjustment of said compensating means, and means, responsive to the variation in such adjustment, for stopping said motor through breaking of said circuit in said device, to terminate the variation in such adjustment.

5. Apparatus according to claim 4, further characterized in that the said make and break devices each comprises a photoelectric cell having circuit-controlling characteristics which are variable in response to variations in the attitude of the press slide and in the adjustment of the said compensating means.

6. Apparatus according to claim 4, further characterized in that the said make and break devices each comprises an electric switch adapted to shift between its open and closed positions in response to variations in the attitude of the press slide and in the adjustment of the said compensating means.

7. Apparatus for controlling the slide movement in a long-bed hydraulic press having slide-actuating rams and related ram advance chambers disposed toward opposite sides of the press slide and means for pumping liquid to said chambers, the said apparatus comprising adjustable compensating means for effecting compensating variations in the volumes of liquid pumped into said chambers, a reversible electric motor for oppositely varying the adjustment of said compensating means, a make and break device for controlling operation of said motor in opposite directions, and control means for said motor comprising a first member, movable in response to variations in the attitude of the press slide, and a second member, movable in response to variations in the adjustment of said compensating means; the two said members being adapted, upon relative movement thereof, to operate said make and break device whereby to modify the control exerted by said control means upon the electric motor; the movement of said first member being in one or the other of opposite directions depending upon the direction of variation in the attitude of the press slide and being adapted to initiate a compensation-yielding variation in the adjustment of said compensating means; and the movement of said second member being subsequent to and in the same direction as that of said first member and being adapted to terminate the variation of such adjustment.

8. Apparatus according to claim 7, further characterized in that the said make and break device comprises two photoelectric cells for controlling operation of said motor in opposite directions, and one of the said movable members has a shutter opening therein arranged to move, upon relative movement of said two members, between a non-registering position, preventing passage of light to either of said cells, and either of two different registering positions, permitting passage of light to one or the other of said cells.

9. Apparatus according to claim 7, further characterized in that the said make and break device is mounted upon and moves with one of the mentioned movable members.

10. Apparatus according to claim 7, further characterized in that the said control means comprise a differential assembly coacting with and deriving its operation from the movement of opposite sides of the press slide, that the said first movable member is adapted to be rotated by said differential assembly, that the said second movable member is adapted to be rotated by said electric motor.

11. Apparatus according to claim 7, further characterized in that the said control means comprise a differential assembly coacting with and deriving its operation from the movement of opposite sides of the press slide, a rack, coacting with and driven by said motor, that the said first movable member is adapted to be rotated by said differential assembly and the said second movable member is adapted to be rotated by said rack.

12. Apparatus according to claim 7, further characterized in that the said make and break device comprises an electric switch, and one of the said movable members has a cam surface thereon, arranged to operate said switch upon movement of said first member and to discontinue the operation of the switch upon subsequent movement of the said second member.

13. Apparatus for controlling the slide movement in a long-bed hydraulic press having slide-actuating rams and related ram advance chambers disposed toward opposite sides of the press slide and means for pumping liquid to said chambers, the said apparatus comprising adjustable compensating means for effecting compensating variations in the volumes of liquid pumped into said chambers, means responsive to variations in the attitude of the press slide, for initiating variations in the adjustment of said compensating means, and means, responsive to such varia-

tions in adjustment, for terminating variations in such adjustment.

14. Apparatus for controlling the slide movement in a long-bed hydraulic press having slide-actuating rams and related ram advance chambers disposed toward opposite sides of the press slide and means for pumping liquid to said chambers, the said apparatus comprising adjustable compensating means for effecting compensating variations in the volumes of liquid pumped into said chambers, and control means comprising a first control member, movable in response to variations in the attitude of the press slide, for initiating a variation in the adjustment of said compensating means, and a second control member, adapted, in direct response to such variations in adjustment, to pursue a follow-up movement relatively to the movement of said first control member, for terminating the variation in the adjustment of said compensating means.

15. Apparatus for controlling the slide movement in a long-bed hydraulic press having slide-actuating rams and related ram advance chambers disposed toward opposite sides of the press slide and means for pumping liquid to said chambers, the said apparatus comprising adjustable compensating means for effecting compensating variations in the volumes of liquid pumped into said chambers, actuating means for varying the adjustment of said compensating means, and control means comprising two photoelectric cells adapted to control the operation of said actuating means in opposite directions, the changes in the operating characteristics of the cells, to effect such control, being derived from variations in the attitude of the press slide and from subsequent variations in the adjustment of said compensating means.

16. Apparatus for controlling the slide movement in a long-bed hydraulic press having slide-actuating rams and related ram advanced chambers disposed toward opposite sides of the press slide and means for pumping liquid to said chambers, the said apparatus comprising adjustable compensating means for effecting compensating variations in the volumes of liquid pumped into said chambers, actuating means for varying the adjustment of said compensating means, and control means comprising two electric switches adapted to control the operation of said actuating means in opposite directions, the shifting of said switches between open and closed positions, to effect such control being derived from variations in the attitude of the press slide and from subsequent variations in the adjustment of said compensating means.

17. Apparatus for controlling the slide movement in a long-bed hydraulic press having slide-actuating rams and related ram advance chambers disposed toward opposite sides of the press slide and means for pumping primary supplies of liquid to said chambers, the said apparatus comprising a compensator pump for effecting compensating variations in the said volumes of primary liquid supplies, a reciprocable adjustment member of said compensator pump, adapted to effect variations in the flow of liquid therethrough, a pair of racks disposed at opposite sides of the press, a pair of shafts coacting with and turned to similar degrees by said racks in consequence of uniform advance movement of the press slide, a mechanism having a first member adapted to move in response to any difference in the degrees of rotation of the said pair of shafts and a second member adapted to coact with said first member upon such movement to control an electric circuit, a motor controlled by said circuit and adapted when operated to start operation of said reciprocable adjustment member and to actuate said second member in a follow-up movement relatively to said first member whereby to restore the relative positions of said two members and limit the operation of the motor and of the adjustment member.

18. Apparatus for controlling the adjustment in the rate of flow of a fluid pump having a movable flow-rate adjusting member, the said apparatus comprising a motor for moving said adjusting member, a speed-reducing connection between the motor and the flow-rate adjusting member adapted to limit the latter member to relatively slow movement, two coacting control members for controlling said motor, means responsive to movement of said control members relatively to each other for starting and stopping said motor, a movement of a first one of said control members from an initial relationship relatively to the second control member causing said motor to start, and the second of said members having a continuously operable connection to said adjusting member and being adapted, when the motor is operated, to derive a follow-up motion from the adjusting member, in the same direction as the mentioned movement of said first control member, whereby to bring the two control members into their mentioned initial relationship, to stop the motor.

19. Apparatus for controlling the rate of delivery of fluid to a chamber of a fluid-actuated motor; comprising a pump adapted to pump fluid to the chamber, adjustable flow-varying means adapted to vary the rate of delivery of fluid from said pump to said chamber, actuating means adapted to actuate said flow-varying means, and control means for controlling the operation of said actuating means; the said control means comprising two coacting members adapted to control the operation of said actuating means whereby to effect adjustment of the flow-varying means to increase or decrease the flow of fluid to said chamber, the said two members being initially movable relatively to each other from an initial relationship in response to movement of a driven member of said motor, different than a predetermined movement thereof, to initiate operation of said actuating means to correct such movement, and subsequently movable relatively to each other, back to said initial relationship, in direct response to the mentioned operation of said actuating means, whereby to terminate correction of such movement.

20. Apparatus for controlling the adjustment in the rate of flow of a fluid pump having a movable flow-rate adjusting member, the said apparatus comprising a motor, two coacting control members for controlling said motor, means responsive to movement of said control members relatively to each other, for starting and stopping said motor, a movement of a first one of said control members from an initial relationship relatively to the second control member causing said motor to start, and the second of said members having a continuously operable connection to said adjusting member and being adapted, when the motor is operated, to derive a follow-up motion from the adjusting member, in the same direction as the mentioned movement of said first control member, whereby to bring the two control members into their mentioned initial re-

lationship, to stop the motor, the said apparatus being further characterized in that the said adjusting member is reciprocable and adapted to reversibly vary the flow of fluid through the pump; in that the said motor is reversible; and in that the said two control members are movable in opposite directions whereby to control the starting and stopping of the motor in the reverse operations thereof.

21. Apparatus for substantially maintaining a predetermined relationship in movements of two elements, comprising separate driving means for each element, compensating means adapted to modify the movements of said elements, a movable adjustment member for said compensating means for adjusting the modifying effect of the latter upon the movements of the two elements, actuating means for actuating said adjustment member, and control means for controlling the operation of said actuating means; the said control means comprising two coacting members initially movable relatively to each other from an initial relationship, in response to departure of the two elements from their predetermined relationship of movement, to initiate operation of said actuating means of a character adapted to restore the said predetermined relationship, and subsequently movable relatively to each other, back to said initial relationship, in response to the mentioned operation of said actuating means, to terminate such operation of the actuating means.

22. Apparatus according to claim 21, further characterized in that a first of said coacting members is operatively connected to both the driven elements and adapted to move in response to movements of the latter other than in the mentioned predetermined relationship and a second of said members has a continuously operable connection to the mentioned actuating means adapting the second member to pursue a follow-up movement in the same direction as the first member.

23. Apparatus for substantially maintaining a

predetermined relationship in movements of two elements, comprising separate driving motors for driving each element, a compensating motor adapted to modify the relative movements of said elements to compensate for departure from said predetermined relationship, a movable control device adapted to control the operation of the compensating motor, an adjustment motor adapted to operate said control device, and compensation control means for controlling the operation of said adjustment motor; the said compensation control means comprising two coacting members, a first of the latter members being movable from an initial relationship relatively to the other member, in response to departure of the two elements from their predetermined relationship of movement, to start the adjustment motor and thereby adjust the compensating motor to restore the said predetermined relationship, and a second of said two coacting members having a continuously operable connection to said adjustment motor adapting it to pursue a follow-up motion in the same direction as the mentioned movement of the first member, whereby to bring the two said members into their mentioned initial relationship, to stop the adjustment motor.

24. Apparatus according to claim 23, further characterized in that the compensating motor, the adjustment motor and the two mentioned members of the compensation control means are reversible in operation whereby to provide acceleration or deceleration of either of the two elements to restore the latters' predetermined relationship.

25. Apparatus according to claim 23, further characterized in that the compensation control means include electric apparatus, responsive to movement of the mentioned two members from an initial relationship to start the adjustment motor and to movement of the two members back to initial relationship to stop the adjustment motor.

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