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[54] **ELECTRICAL CONTROL SYSTEM FOR A POWER PRESS**

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[52] **U.S. Cl.** ..... **100/53,** 192/131 R

[51] **Int. Cl.** **B30b 15/14**

[58] **Field of Search** ..... 100/53; 192/143, 192/131 R

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[57] **ABSTRACT**

An electrical control system for a power press having three different modes of operation known as "inch," "single stroke," and "continuous." The control system incorporates numerous safety features, one of which is that two "run" buttons must be held depressed at all times during the "inch" mode, and during the major portion of the downstroke in the "single stroke" mode so as to avoid the possibility of attempted single-handed operation by the operator, which would leave one hand free to enter the path of the ram. In the "single stroke" mode, a malfunction of the relay which stops the press ram at the end of each cycle renders the reset circuit inoperative so that the malfunction must be corrected before press operation can be resumed. In the absence of a malfunction, the resetting is performed automatically. In the "continuous" mode, the "run" buttons must be held down during a major portion of the downstroke of the ram, and an additional button must be depressed during the first stroke of the ram in order to put the press into the "continuous" mode of operation. If the mode selector switch is turned from one mode position to another, the system must be reset so that any malfunctions will be detected, thereby preventing the operator from switching from one mode to another to circumvent the effect of a malfunction. Various other fail safe features, redundancies, and double redundancies are also included.

13 Claims, 4 Drawing Figures

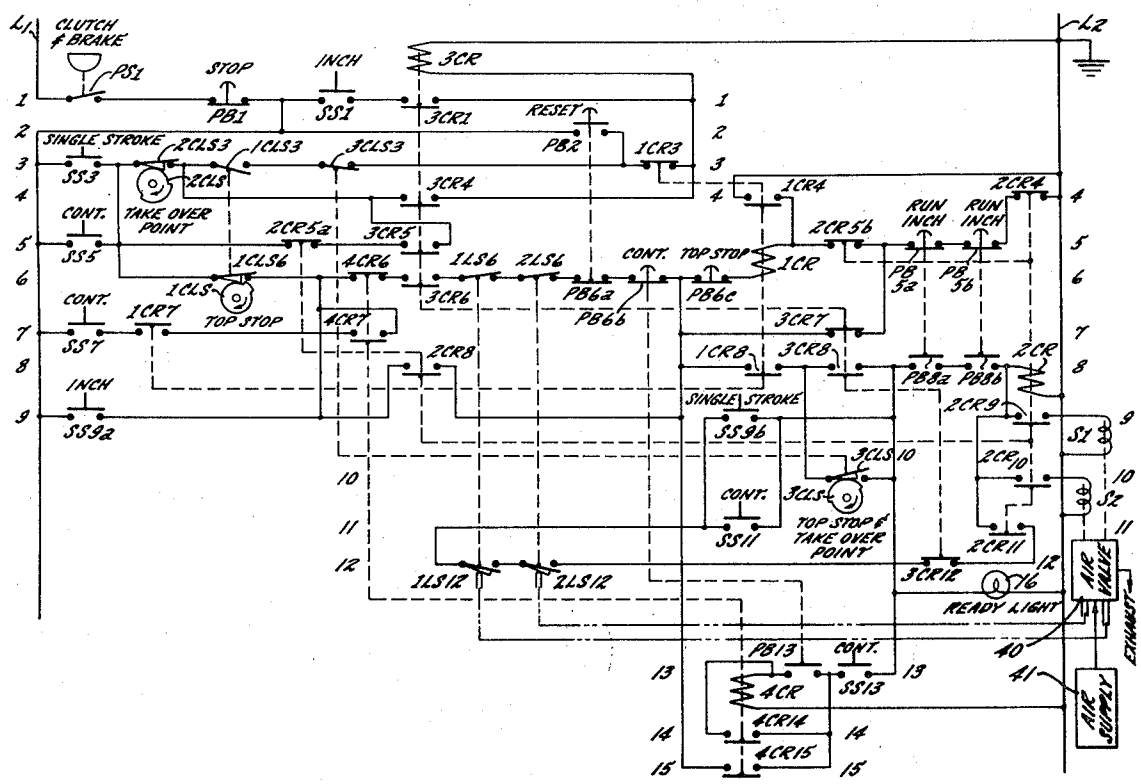
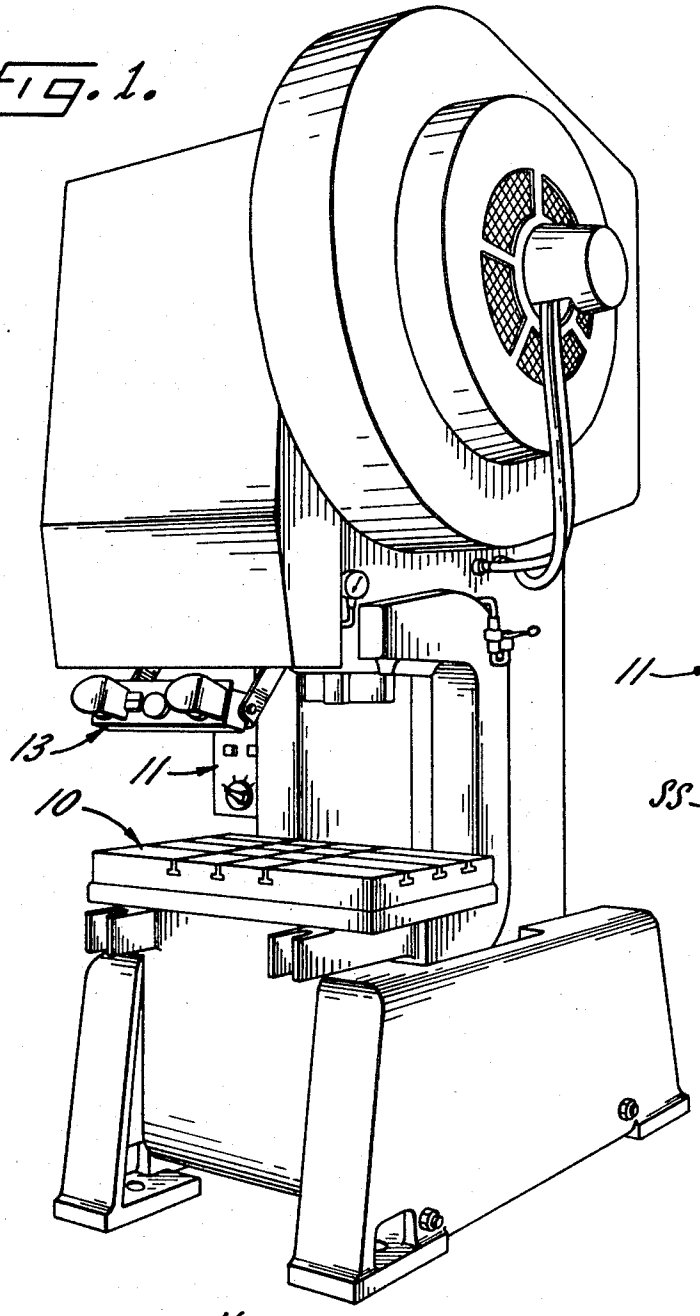


Fig. 1.



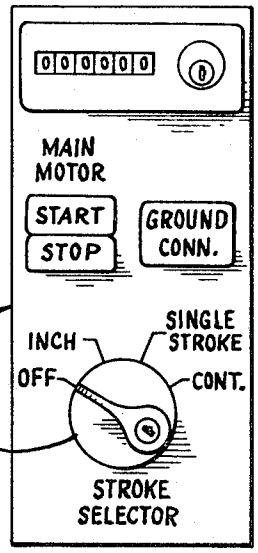


Fig. 3.

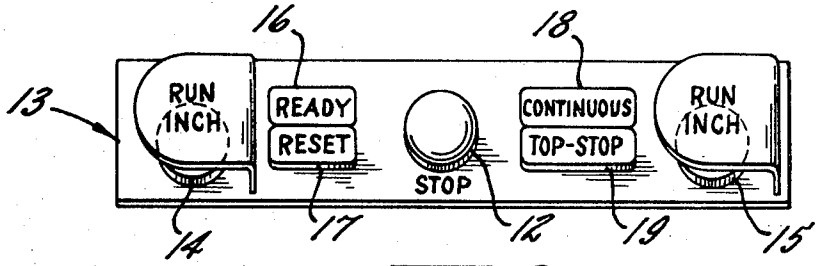


Fig. 2.

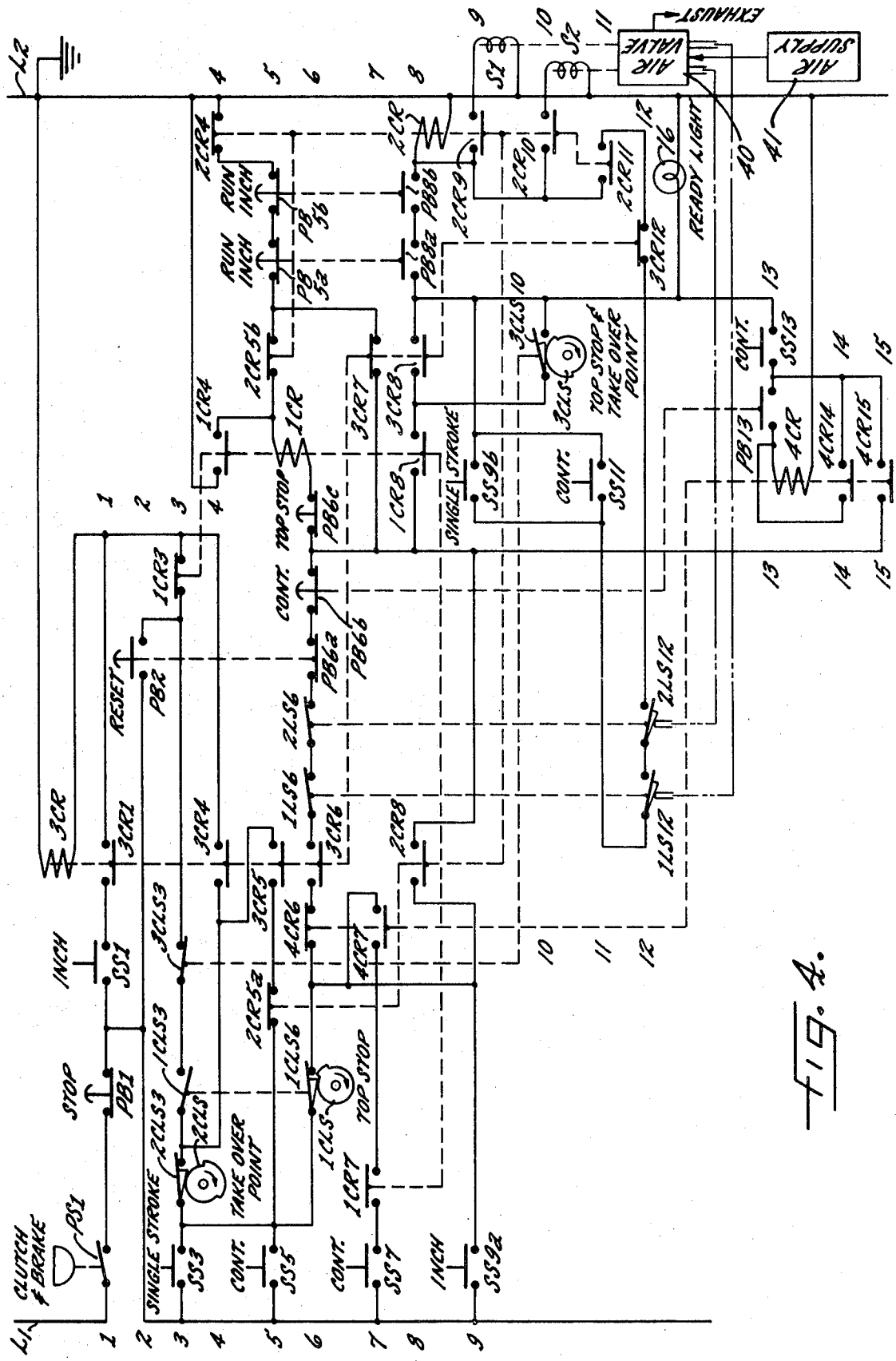

L2
L1
CLUTCH & BRAKE
PS1
SINGLE STROKE
SS3
CONT.
SS5
CONT.
SS7
INCH
SS9a2
STOP
PB1
INCH
SS1
RESET
PB2
CONT. TOP STOP
PB6c
PB6a
PB6b
SINGLE STROKE
SS9b
CONT.
SS11
TOP STOP TAKE OVER POINT
3CLS10
3CLS
TAKE OVER POINT
2CLS3
2CLS
1CLS6
1CLS
TOP STOP
1CLS
RUN INCH
PB5b
RUN INCH
PB5a
CONT.
SS13
PB13
AIR VALVE
AIR SUPPLY
EXHAUST
READY LIGHT
S1
S2
3CR
1CR3
3CR1
3CR4
1LS6
3CR6
3CR5
4CR6
4CR7
2CR8
2LS12
1LS12
1CR4
2CR5b
1CR
3CR7
3CR8
1CR8
2CR4
2CR
2CR9
2CR10
2CR11
3CR12
4CR
4CR14
4CR15
2CR5a
4CR5
1CR7
4CR7
3CR5
2LS6
1LS6
3CR6
2CR8
2LS12
1LS12
40
41

FIG. 4.

ELECTRICAL CONTROL SYSTEM FOR A POWER PRESS

DESCRIPTION OF THE INVENTION

The present invention relates generally to power presses and, more particularly, to an improved control system for a power press.

Efforts have been made over the years to improve the safety and reliability of control circuitry for power presses and in particular to prevent spurious or accidental cycling which is a hazard to both the operator and the equipment. For example, where a certain safety function has been performed by a particular component, alternate or redundant means have been provided to insure that the function was performed. However, where the function has been performed by the alternate means, the press has continued to be operable even though there is evidence that a failure has occurred. Thus it has been necessary to rely upon periodic inspection procedures to being to light component failures in the system. While it has been known to employ warning signals to indicate failure of a safety component, this has not provided adequate protection because of the tendency of some operators to ignore warning signals in order to continue production, and because of the loss of a warning when the warning device itself fails to function.

Another problem with previous press control systems is that in the case of operation of the press in the "continuous" or automatically repeating mode, operation of the press, once initiated, has continued indefinitely and reliance, particularly where foot switch controls have been used has been placed upon use of "point of operation " guards to block access to the working area and upon the use of an emergency stop button. Unfortunately, in shops where formal safety procedures are lacking, such guards are often dispensed with. Similarly, in the conventional "inching" control which is intended primarily for use by skilled setup personnel in jogging the slide through small increments of movement it has been possible to complete a working cycle, and accidents have occurred when the press operator has resorted to inching control to do production work.

A further difficulty with previous press control systems is that the stroke selector switch which is employed to establish a desired mode of operation can generally be switched from one mode to another while the press is in operation and while this does not stop movement of the slide, operation of the press can then be reinitiated by use of the operating means alone. This may create a hazard, particularly if the setting of the selector is changed accidentally or without knowledge of the operator.

In general, while efforts have been made to incorporate "fail safe" techniques in controls for power presses, prior press control systems have not employed such techniques fully to the point of cylical testing of the elements which are relied upon to insure that any failure occurs in a mode which is safe to both the operator and the equipment.

It is, accordingly, an object of the present invention to provide a control system for a power press which is inherently safer and more foolproof than systems which have been available in the past, and in which failure of a component serves to bring the press to a safe stop and minimizes the opportunities provided to the press operator to re-establish the system in operation by manipulation of the controls. It is specifically an object of the invention to provide a press control system which guards against the effect of sticking relays and which prevents the operator of the press from counteracting the sticking of relays by the expedient of manipulating the operating means.

It is another object of the invention to provide a press control system which prevents the carrying out of production work on the press by resort to the "inch" mode, with any loss of the normal safety features of "inch" mode, in the event that regular operation in the "run" mode becomes impossible by reasons of circuit malfunction.

It is still another object of the present invention to provide increased safety when the press is operated in the "continuous" mode and which insures that the press will not be operated continuously except as a result of predetermined and essential action on the part of the operator. Thus it is an object to provide a press control system which enables the press to be more safely operated in the "continuous" mode.

It is a general object of the invention to provide a press control system which provides additional safety in all modes of operation, even where a foot switch is employed instead of the usual palm-operated "run" buttons.

It is another object of the present invention to provide a press control system which employs a mode selector switch but in which any attempt to change the mode during the course of a cycle results in shut-down of the press and requires resetting before operation may be resumed with the normal operating means.

It is yet another object of the invention to provide a press control system which makes increased use of fail-safe techniques and in which failure of a component not only results in a safe condition of shut-down but in which redundant circuit elements, provided in the interest of safety, are automatically and continuously checked either during or after each press operation.

Then, too, it is an object of the invention to provide a control system for a power press which is conveniently switchable to provide the various modes of operation, which provides a high level of flexibility, and which is easily operated and highly economical as well as being easily and quickly serviced in the event that servicing becomes necessary.

Other objects and advantages of the invention will become apparent upon reading the attached detailed description and upon reference to the drawings in which:

FIG. 1 is a perspective view of a power press controlled by a control system embodying this invention;

FIG. 2 is an elevation of one of the control panels on the front of the press of FIG. 1;

FIG. 3 is an elevation of the other control panel on the front of the press of FIG. 1; and

FIG. 4 is a schematic diagram of the control system associated with the control panels of FIGS. 2 and 3 for controlling the press of FIG. 1.

While the invention will be described in connection with certain preferred embodiments, it will be understood that it is not intended to limit the invention to these particular embodiments. On the contrary, it is intended to cover all alternatives, modifications and equivalent arrangements as may be included within the spirit and scope of the invention.

Turning now to the drawings and referring first to FIG. 1, there is shown a power press having a conventional type ram mounted for vertical reciprocating movement. As the ram is lowered, it strikes a workpiece positioned on the worktable **10**, and then the ram is raised for the next operating cycle. A stroke selector switch SS is provided on one of the control panels (see FIG. 3) on the front of the press to permit selection of three different modes of operation, namely the "inch" mode, the "single stroke" mode, and the "continuous" mode. The press can be stopped at any time by turning the selector switch SS to the "off" position or by pressing a "stop" button **12** on the second control panel (see FIG. 2) on the front of the press. The second control panel **13** represents the operator's control station, and includes two palm-sized "run-inch" buttons **14** and **15**, a "ready" light **16**, a "reset" button **17**, a "continuous" button **18**, and a "top stop" button **19**.

When the selector switch SS is set to the "inch" mode position, the operator depresses and releases the "reset" button **17**, after which the "ready" light **16** is illuminated. The operator then depresses and releases both "run-inch" palm-buttons **14** and **15** as desired to "inch" the ram through its stroke. As will be explained in more detail below, both buttons must be concurrently released whenever either button is released before the "inch" mode of operation can be repeated.

When the selector switch SS is set to the "single stroke" position, the operator again initiates press operation by depressing and releasing the "reset" button **17**, after which the "ready" light **16** is illuminated. The operator then depresses both "run-inch" palm-buttons and holds them depressed through the major portion of the downstroke of the press ram. The ram will then continue in motion stopping at the top of its stroke. If either button **14** or **15** is released during the downstroke of the press ram, both buttons must be concurrently released and re-depressed before the ram motion can be re-initiated. The ram will stop at the top of its stroke regardless of whether either or both buttons are held depressed through the end of the stroke.

When the selector switch SS is set to the "continuous" mode position, the operator again initiates operation of the press by depressing and releasing the "reset" pushbutton **17**, after which the "ready" light **16** is illuminated. The operator then depresses both "run-inch" palm-buttons **14** and **15** and holds them depressed through the major portion of the downstroke, and in addition he depresses the "continuous" pushbutton **18** sometime during the first stroke. The press will then continue to run. To interrupt the continuous operation and stop the ram at the top of a stroke, the operator momentarily depresses the "top stop" pushbutton **19**.

Turning next to FIG. 4 for a more detailed description of the internal control system which responds to the various manually initiated operator commands described above, it should first be noted that all switches and contacts are shown in their normal positions prior to actuation of any of the manual controls, with all relays de-energized, and with all cams in their 0° positions. All the cams are connected for rotation in synchronism with movement of the press ram, with each cam completing one revolution for each complete cycle of reciprocating movement of the ram; that is, each cam rotates 180° during each downstroke of the ram, and another 180° during each up stroke of the ram, or 360° for each complete stroke cycle of the ram, with the 0° position normally being at the top of the stroke. All relay coils are identified by the designator "CR" with sequential prefix numbers, e.g., "1CR"; all relay contacts are identified by the designator of their controlling coil followed by the number of the line (see left side of FIG. 4) of the circuit diagram in which the respective contacts appear in FIG. 4, and further followed by suffix letters if two or more contacts controlled by the same coil appear in the same line, e.g., "2CR5a," "2CR5b"; all switch-controlling cams are identified by the designator "CLS" with sequential prefix numbers, e.g., "1CLS"; all cam-controlled switches are identified by the designator of their controlling cam followed by the number of the line of the circuit diagram in which the respective switches appear in FIG. 4, e.g., "1CLS3"; all pushbutton-operated switches are identified by the designator "PB" followed by the number of the line of the circuit diagram in which the respective switches appear in FIG. 4, and further followed by suffix letters if two or more pushbutton-operated switches appear in the same line, e.g., "PB5a," "PB5b"; all air pressure operated switches are identified by the designator "PS" followed by the number of the line of the circuit diagram in which the switch appears and all contacts controlled by the selector switch SS are identified by the designator "SS" followed by the number of the line of the circuit diagram in which the respective contacts appear in FIG. 4 and further followed by suffix letters if two or more contacts controlled by the selector switch appear in the same line, e.g., "SS9a," "SS9b."

The main power supply to the circuit illustrated in FIG. 4 is applied across lines L1 and L2. The primary outputs of the circuit are represented by solenoids S1 and S2 which control an air valve unit **40** of the type described in more detail in the assignee's copending application Ser. No. 122,008, Filed Mar. 8, 1971, entitled "Safety Valve Assembly for Controlling Clutch and Brake in Power Press or the Like," and invented by Kenneth R. Mahorney. As indicated by the title of the copending application, the air valve unit **40** controls the clutch and brake in the main press drive, in response to energization and de-energization of the two solenoids S1 and S2. More particularly, concurrent energization of both solenoids S1 and S2 engages the clutch of the drive unit, and releases the brake of the drive unit, whereas de-energization of either solenoid S1 or S2 disengages the clutch and engages the brake as described in more detail in the aforementioned copending application. In addition to controlling the clutch and brake, the air valve unit **40** mechanically actuates two pairs of limit switches **1LS6, 1LS12** (corresponding to limit switch **61** in the copending application) and **2LS6, 2LS12** (corresponding to limit switch **62** in the copending application). When the solenoids S1 and S2 are de-energized, the limit switches **1LS6** and **2LS6** are closed and limit switches **1LS12** and **2LS12** are open. As indicated schematically in FIG. 4, the valve operated by solenoid S1 controls switches **1LS6** and **1LS12** while the valve operated by solenoid S2 controls switches **2LS6** and **2LS12**. Since the limit switches are mechanically actuated by the valves, of course, they provide a means of determining any malfunction of the valves.

When the press ram is at the top of its stroke, the control circuit is in the state illustrated in FIG. 4, with the brake engaged and the clutch disengaged. To insure

that the air supply 41 for the air valve unit 40 is sufficient for proper operation of the clutch and brake, this air supply controls a switch PS1, closing the switch PS1 when the air pressure is above a prescribed minimum pressure. If the switch PS1 is open due to insufficient air pressure at the source, power is cut off from the entire control system so that the press is inoperative until the requisite air pressure is provided.

The "stop" pushbutton 12 on the press control panel 13 controls a switch PB1 connected in series with the switch PS1 and is normally closed. If the operator presses the "stop" pushbutton 12, the switch PB1 is opened to cut off the power supply from the entire control system, with the same effect as opening of the switch PS1. Turning now to the "single stroke" mode of operation of the control system shown in FIG. 4, when the selector switch SS on the press control panel 11 is set to the "single stroke" position, it closes selector switch contacts SS3 and SS9b, the function of which will be apparent from the ensuing description. Next the operator depresses the "reset" pushbutton 17 on the control panel 13, thereby opening switch PB6a to prevent an "anti-repeat" relay 1CR from energizing before the "reset" button 17 is released. Next, the "reset" button 17 closes switch PB2 to energize a checking relay coil 3CR via normally closed contact 1CR3. The relay coil 1CR which controls contact 1CR3 is an anti-repeat relay which automatically stops the press ram at the end of each up stroke in the "single stroke" mode, as will be described in more detail below. If this relay coil 1CR becomes stuck in its energized position due to a malfunction, the contact 1CR3 remains open and the checking relay coil 3CR cannot be energized when the reset button is depressed. Thus, the contact 1CR3 represents a safety feature which prevents operation of the press in the event of a malfunction of the anti-repeat relay coil 1CR. It can be seen that it is important to open switch PB6a before closing switch PB2 because otherwise relay coil 1CR could energize and open contact 1CR3 to de-energize coil 3CR before it locked itself in (the locking in of 3CR will be described below).

If the contact 1CR3 is in its normally closed position, thereby energizing the relay coil 3CR upon closing of the reset switch PB2, contact 3CR4 closes to bypass the reset switch PB2 and switches 1CLS3 and 3CLS3 to lock in the relay coil 3CR through switch SS3 and a normally closed cam-operated switch 2CLS3. Consequently, if the selector switch SS is moved to a different position, the relay coil 3CR is de-energized to de-actuate the press drive by opening contact 3CR6 and thereby de-energizing solenoids S1 and S2. This is an important safety feature of the present control system because press operators sometimes attempt to overcome a press shutdown effected by a safety feature, while the press is in the "single stroke" mode, by switching the selector switch SS to a different position. With the control system of the present invention, however, switching the selector switch SS to a different position immediately de-energizes the relay coil 3CR so that it is necessary for the operator to again depress the reset pushbutton, thereby initiating all of the automatic checks effected by the closing of the reset switch PB2.

Energization of relay coil 3CR also opens contact 3CR7 so as to prevent a short circuit to ground after the reset button is released to close switch PB6a. The relay coil 3CR also closes contact 3CR8 to enable subsequent energization of relay coil 2CR via switches to be described below.

In addition to the contact operation mentioned above, energization of the checking relay coil 3CR closes contacts 3CR1 and 3CR5 and opens contact 3CR12, all for purposes to be discussed in detail below.

When the operator releases the "reset" button 17, switch PB2 returns to its normal open position and switch PB6a returns to its normal closed position. As mentioned previously, the opening of switch PB2 does not result in de-energization of the relay coil 3CR since this relay is locked in through its own contacts 3CR4. The closing of switch PB6a energizes the anti-repeat relay coil 1CR via switches SS3, 1CLS6, 4CR6, 3CR6, 1LS6, 2LS6, PB6a, PB6b, PB6c, 2CR5b, PB5a, PB5b, and 2CR4. If the run relay coil 2CR remains energized due to a malfunction during the previous cycle, contacts 2CR5b and 2CR4 remain open so that relay coil 1CR cannot be energized, thereby providing a safety check on the run relay 2CR.

It will be appreciated that the anti-repeat relay 1CR provides a safety check on all the switches included in its energization circuit. More specifically, if the relay 1CR is not energized, its contact 1CR8 remains in the open position, thereby making it impossible to energize the solenoids S1 and S2 so that the press drive cannot be actuated, and preventing illumination of the "ready" light. Thus, the relay 1CR provides a safety check on the two "run-inch" buttons 14 and 15 which control switches PB5a and PB5b (this is an important safety check because the press operators sometimes attempt to effect permanent actuation of the "run-inch" palm-buttons which control switches PB5a and PB5b by wedging or taping the buttons in their depressed positions, so that the operator can control the press by single handed operation of only one of the pushbuttons; such single handed operation is an inherently dangerous situation due to the fact that the operator would have one hand free to manipulate the workpiece within the closing travel path of the press ram); the "top-stop" pushbutton 19 controlling switch PB6c; the "continuous" pushbutton 18 which controls switch PB6b; the "reset" pushbutton 17 which controls switch PB6a; the air valves that control switches 1LS6 and 2LS6; relay coil 3CR which controls contact 3CR6 (which is open if the relay coil 3CR is not locked in through its own contacts); relay coil 4CR which controls contact 4CR6 (if this relay 4CR is stuck in its energized position, contact 4CR6 remains open); cam 1CLS as well as the ram position reflected by the cam (if the ram has not completed a full cycle in its previous stroke, and thus is not properly positioned to begin a new stroke, so that the ram is between its 320° and 340° positions, the cam 1CLS holds the switch 1CLS6 open); and the selector switch SS which controls switch SS3.

When the relay 1CR is energized, it closes a contact 1CR4 so as to bypass switches 2CR5b, PB5a, PB5b, and 2CR4, so that the relay 1CR remains energized independently of these four switches. The relay 1CR also closes contact 1CR8 which prevents energization of the press drive unit in the event of a failure of the relay 1CR to energize. The closing of contact 1CR8 also energizes the "ready" light 16 on the control panel 13 of the press, so as to indicate to the operator that the press is ready for operation in the selected mode.

After the "ready" light 16 is energized, the operator must depress both "run-inch" pushbuttons 14 and 15

to initiate a stroke of the press ram, and these buttons must be held depressed until the ram has traversed at least 150° of its complete stroke cycle, i.e., until the ram is near the bottom of the down stroke. Depression of the pushbuttons **14** and **15** opens switches PB5a and PB5b, but this does not affect the energization of relay 1CR since the closing of contact **1CR4** bypassed the two switches PB5a and PB5b. The same pushbuttons **14** and **15** close switches PB8a and PB8b, thereby energizing the run relay 2CR which closes contacts **2CR9** and **2CR10** to concurrently energize the solenoids S1 and S2 and thereby acutate the press drive. As the press drive is acutated, the opening of the air valves within the air valve unit **40** closes switches **1LS12** and **2LS12** for a purpose to be described below. The same air valves also open switches **1LS6** and **2LS6** thereby opening the orginal energizing circuit to relay 1CR. However, the energization of relay 2CR closes **2CR8** so that the relay 1CR remains energized through a circuit extending from switch **1CLS6** through **2CR8** and switch PB6c. This places energization of the relay 1CR under the control of relay 2CR, since de-energization of relay 2CR opens the contact **2CR8** and thereby de-energizes relay 1CR. This is an important safety feature because it means that if the operator releases either of the "run-inch" pushbuttons **14** or **15** during the down stroke of the ram, he must release both pushbuttons **14** and **15** before operation can be resumed. For example, assume that switch PB8a is opened by release of the corresponding pushbutton, but switch PB8b remains closed because the operator has taped or wedged the corresponding pushbutton in its depressed position. In this situation, the relay 2CR is de-energized by the opening of switch PB8a, thereby stopping the press. In addition, however, relay contact **2CR8** opens, thereby de-energizing the anti-repeat relay 1CR. At this point the only way to resume press operation is to re-energize relay 1CR, since contact **1CR8** must be closed to energize the run relay 2CR and re-start the press. However, relay 1CR cannot be re-energized unless both switches PB5a and PB5b are closed, and thus the operator must release both of the "run-inch" pushbuttons. Consequently, in order to re-start the press, the operator must release both "run-inch" pushbuttons so as to allow them to return to their normal positions.

When the ram traverses 95° of its stroke cycle, the cam 3CLS closes a switch **3CLS10** so as to bypass the contact **3CR8**, thereby enabling an alternate energizing circuit for the run relay 2CR after the checking relay 3CR is de-energized. The cam 3CLS also opens a switch 3CLS3 for a purpose to be described below.

When the ram traverses 150° of its stroke cycle, the cam 2CLS opens a switch **2CLS3** so as to de-energize the checking relay 3CR. This returns all of the contacts associated with relay 3CR to their normal positions. The closing of contact 3CR7 has no effect in normal operation of the press since contacts **2CR5b** and **2CR4** are open. However, if a ground exists in the switches PB5a or PB5b or their wiring, for example, the closed contact 3CR7 shorts out the line to this ground via contact **2CR8**, switch **1CLS6** and switch **SS3**, thereby blowing the main circuit fuses. This is an exceptional safety feature, in that it blows the main fuses and shuts down the entire press, but it averts an exceptionally dangerous position in that it prevents the operator from attaining single handed operation by permanently depressing a shorted switch.

Returning to the effect of the de-energization of checking relay 3CR, an alternate energizing path for the run relay 2CR is provided by the opening of contact **3CR8** and the closing of contact **3CR12**. More particularly, the original energizing circuit through contact **3CR8** is opened, and the new energizing circuit is through **2CR11**, **3CR12**, **2LS12**, **1Ls12**, **SS9b**, **3CLS10**, **1CR8**, **2CR8**, **1CLS6**, and **SS3**. (It should be noted that if switch **3CLS10** was not closed at 95°, the takeover sub-mode is not achieved, so that both switches **3CLS10** and **2CLS3** are necessary parts of the takeover system.) At this point the control system is in a "take-over" sub-mode in which the "run-inch" pushbuttons **14** and **15** may be released and the control system automatically takes over to continue completion of the ram stroke cycle in progress. More specifically, the ram cycle is continued since relay 2CR is energized via contact **3CR12** rather than via contact **3CR8** and switches PB8a and PB8b. It will be appreciated that this "take-over" sub-mode is not attained until the ram is 150° into its stroke cycle, i.e., until the relay CR3 is de-energized. At this point in the stroke cycle, the ram has nearly completed its down stroke, and there is little or no danger to the operator's hands. In the event of a malfunction of the relay 3CR or the cam 2CLS or its switch **2CLS3**, the press will stop when the operator releases either one or both of the "run-inch" pushbuttons **14** or **15**, thereby providing the operator with an indication of the malfunction.

When the press ram traverses 320° of its stroke cycle, cam **1CLS** opens a switch **1CLS6** to de-energize the relay 2CR, relay 1CR, and solenoids S1 and S2, thereby disengaging the clutch and applying the brake as previously described and returning all the contacts associated with 1CR and 2CR to their normal positions until initiation of the next operating cycle. Consequently, the ram movement is stopped at the end of its stroke regardless of what the press operator does. The resultant closing of the air valves in the air valve unit **40** opens switches **1LS12** and **2LS12** and closes switches **1LS6** and **2LS6** thereby resetting these switches for the next cycle of operation.

Although the press drive is de-energized when the ram reaches 320° of its stroke cycle, the inertia of the ram carries it on to its 360° point. When the ram traverses 325° of its stroke cycle, the cam 3CLS opens the switch **3CLS10** to provide a redundancy for the switch **1CLS6**. Thus, if the switch **1CLS6** should fail to open at the 320° point, the relay 2CR is still de-energized along with solenoids S1 and S2 at the 325° point by the opening of switch **3CLS10**. The de-energization of relay 2CR in turn de-energizes 1CR by opening contact **2CR8**. In the event of a malfunction in the cam 1CLS, the press will still be stopped by the redundant switch **3CLS10**, but the cam switch **1CLS3** will remain open, thereby resulting in a loss of the automatic reset feature to be described below, providing the operator with an indication of the malfunction.

At the 325° point, the cam 3CLS also closes a switch **3CLS3** to initiate an automatic resetting of the control system. That is, the closing of the switch 3CLS3 has the same effect as the closing of the reset switch **PB2**, since switches **SS3**, **2CLS3**, and **1CLS3** are all closed in series with switch **3CLS3**. Switch **1CLS3** was previously closed at 320° by cam 1CLS when it opened switch **1CLS6**, and switch **2CLS3** was previously closed at 270° by cam 2CLS. However, in the event of a failure

of the relay 1CR to drop out, so that it remains energized, the contact 1CR3 is open so that the automatic reset cannot occur. Furthermore, the system cannot be manually reset by closing the switch PB2 because the contact 1CR3 is located between swtich PB2 and relay 3CR. Nor will holding the "run-inch" palm-buttons 14 and 15 depressed during the entire preceding stroke cycle be effective to continue operation of the machine. Thus, it can be seen that if the anti-repeat relay 1CR is not de-energized at the end of a stroke cycle, the control system cannot be reset until the malfunction is corrected.

When the press ram traverses 340° of its stroke cycle, the cam 1CLS closes switch 1CLS6 to automatically re-energize the anti-repeat relay 1CR via SS3, 1CLS6, 4CR6, 3CR6, 1LS6, 2LS6, PB6a, PB6b, PB6c, 2CR5b, PB5a, PB5b and 2CR4. At this point the control system has been automatically reset and the "ready" light 16 is illuminated to indicate that the press is in condition for another cycle of operation in the "single stroke" mode. It should be noted that this automatic resetting of the control system does not bypass any of the safety checks effected by the manual reset in response to closing of the switch PB2 as described above. This automatic resetting of the control system provides a convenience for the operator in that it enables him to initiate successive single strokes by merely depressing the two "run-inch" palm-buttons 14 and 15 without manually pressing the "reset" pushbutton 17 between successive strokes.

Turning next to the "inch" mode of operation of the illustrative system, this mode of operation is selected by turning the selector switch SS on panel 11 to the "inch" position, thereby opening switch SS3 and closing switch SS9a. This "inch" mode of operation enables the operator to run the press ram through its stroke in small, sequential increments, with a pause after each incremental movement of the ram. Before operation of the press can be commenced in this mode, the control system must be reset by depressing the "reset" pushbutton 17, as in the "single stroke" mode. One difference in the reset operation is that the relay 3CR is locked in through its contact 3CR1 and switch SS1 which is closed in response to setting of the selector switch SS to the "inch" position. Consequently, if the selector switch SS is moved to a different position, the switch SS1 opens to prevent lock-in of the relay coil 3CR so that a manual reset is required to resume operation of the press. Also, the closing of contacts 3CR4 and 3CR5 in response to energization of the relay 3CR serves no functional purpose in this mode, since the switch SS9a is also closed. The opening of contact 3CR12 is also idle since both switches SS9b and SS11 are open in this mode.

When the anti-repeat relay coil 1CR is energized in the "inch" mode, in response to release of the "reset" pushbutton 17, the energization path is the same as that described above for the "single stroke" mode except that switch SS9a replaces switches SS3 and 1CLS6 in the energization circuit for the relay coil 1CR. The cam-operated switch 1CLS6 is the "top stop" switch which is not used in the "inch" mode and therefore need not be checked by including it in the energization path for relay coil 1CR.

After the reset operation is completed, the operator initiates inching, incremental motion of the press ram by simultaneously depressing both of the "run-inch" palm-buttons 14 and 15. To interrupt the inching process, the operator releases either or both of the two "run-inch" palm-buttons. To resume operation, the operator must release both "run-inch" palm buttons and then concurrently re-depress them.

When the "run-inch" pushbuttons are depressed so as to open switches PB5a and PB5b and close switches PB8a and PB8b, the operation is similar to that described above in the "single stroke" mode except that the checking relay 3CR is never de-energized due to the closure of switch SS1. Thus, the switches controlled by the cams 1CLS, 2CLS and 3CLS are all bypassed, either by switch SS1 or switch SS9a, so that there is no "take-over" sub-mode and, therefore, no end-of-cycle operation. Consequently, energization and de-energization of the solenoids S1 and S2 is controlled manually by the run-inch switches PB8a and PB8b.

If the operator releases either of the "run-inch" palm buttons, the opening of the corresponding switch PB8a or PB8b de-energizes the relay 2CR and the solenoids S1 and S2. The resultant closing of the two valves in the air valve unit 40 closes the two limit switches 1LS6 and 2LS6 to enable a re-energizing circuit to the coil 1CR. It will be recalled that energization of the anti-repeat relay coil 1CR is under the control of relay coil 2CR via contact 2CR8 so that the coil 1CR is de-energized each time the coil 2CR is de-energized. To complete the re-energization path to coil 1CR, contacts 2CR5b and 2CR4 are also closed. In order to re-start the press, the operator must release both "run-inch" palm-buttons 14 and 15 to close both switches PB5a and PB5b to energize the relay 1CR. Energization of relay coil 1CR then closes contact 1CR4 to lock in the coil 1CR via contact 1CR4, bypassing switches 2CR5b, PB5a, PB5b, and 2CR4. Contact 1CR8 also closes, thereby enabling the energizing circuit to relay coil 2CR so that the press is started again when the operator concurrently depresses both "run-inch" palm-buttons to concurrently close the two switches PB8a and PB8b.

In the "inch" mode, the press does not stop at the top of each stroke, since the top-stop switches 1CLS6 and 3CLS10 are idle. However, since both of the operator's hands must be on the "run-inch" palm-buttons for the press to run, i.e., there is no "take-over" sub-mode, there is no danger of single handed operation by the operator. When the operator wishes to stop the press as the ram inches toward the top of its stroke, he merely releases either or both of the "run-inch" palm-buttons. The circuit then automatically returns to its original reset configuration, ready for the operator to resume the inching process. If, however, the operator changes the position of the selector switch SS, the relay coil 3CR drops out due to the opening of switch SS1, and then coil 1CR drops out due to the opening of SS9a and the reset configuration of the circuit is lost.

To operate the press in the "continuous" mode, the operator switches the selector switch SS on panel 11 to the "continuous" position, thereby closing switches SS5, SS7, and SS11. In this mode, the operator initiates press operation in the same manner as in the "single stroke" mode, then depresses an additional "continuous" pushbutton 18 so that the control system automatically recycles the press until it is stopped. When the operator depresses and releases the "reset" pushbutton 17, and then depresses the two "run-inch" palm-buttons 14 and 15 to initiate press operation, the operation of the control system illustrated in FIG. 4 is the

same as described above for the "single stroke" mode, except that switch SS5 takes the place of switch SS3. All the safety features which are operative during the "single stroke" mode are also operative during the downstroke of the initial cycle of the "continuous" mode.

During the downstroke of the initial cycle, when the press ram reaches the 150° point, the control system operates in the "take-over" sub-mode. At this point, the operator can remove both hands from the "run-inch" palm-buttons and, if the operator does nothing more, the press will continue to operate precisely as in the "single stroke" mode, even though the selector switch SS is in the "continuous" position. However, if the operator depresses the "continuous" pushbutton during the initial cycle, the control system takes over operation of the press and causes it to operate in a continuous, recycling fashion with no stopping at the top of each stroke, until the operator depresses the "top stop" pushbutton **19.** The requirement that the operator depress the "continuous" pushbutton in order to achieve the continuous mode of operation is an important safety feature, in that it prevents the operator from inadvertently depressing both "run-inch" palm-buttons thinking he is in the "single stroke" mode, when in fact he is in the "continous" mode, and having the press continue in operation when in fact the operator would expect it to stop at the completion of a single stroke cycle. Thus, unintentional continuous operation is avoided by the requirement that the operator both set the selector switch SS in the "continuous" position and additionally depress the "continuous" pushbutton **18** at some time during the initial cycle of operation.

Returning now to FIG. **4,** when the operator depresses the "continuous" pushbutton **18,** a switch **PB6b** is opened and **PB13** closes. The closing of switch **PB13** energizes a relay coil **4CR** via **PB13, SS13, 3CLS10,** (or **3CR8** if the "continuous" pushbutton is depressed before 150° of the first cycle is completed, i.e., when relay coil **3CR** is still energized), **1CR8, 2CR8, 1CLS6,** and **SS5.** It will be noted that this energizing path provides a number of safety features, namely: the coil **4CR** cannot be energized unless the selector switch SS is in the "continuous" position, so that depressing the "continuous" pushbutton **18** in either the "single stroke" or "inch" mode cannot energize coil **4CR** to produce accidental continuous operation; coil **4CR** cannot be energized if the "continuous" pushbutton is depressed before the ram stroke is initiated (even if coil **4CR** is energized due to a malfunction, the open contact **4CR6** prevents coil **1CR** from energizing so as to prevent stroke initiation); if the "continuous" pushbutton is depressed during the first 150° of the initial downstroke of the press ram, the coil **4CR** is energized but the operator must still keep both hands on the "run-inch" palm-buttons until the coil **3CR** drops out at the 150° point, thereby closing contact **3CR12,** and keeping coil **2CR** energized in the continuous mode.

Energization of the relay coil **4CR** closes contact **4CR7** to bypass the top stop switch **1CLS6** via **1CR7** and **SS7** to eliminate the top stop feature of the "single stroke" mode of operation. Finally, energization of coil **4CR** closes contacts **4CR14** and **4CR15** to lock in the coil **4CR** via **4CR14, 4CR15, 2CR8, 4CR7, 1CR7,** and **SS7,** thereby bypassing the top stop backup switch **3CLS10** and **1CR8.**

When the operator releases the "continuous" pushbutton, switch **PB6b** closes and switch **PB13** opens, but the relay coil **4CR** remains energized due to its lock-in energizing circuit as described above. The control system is now in the "continuous" mode of operation, with relay coils **4CR, 2CR,** and **1CR** all energized, independently of the switches controlled by cams **CLS1, CLS2,** and **CLS3.** Consequently, the press continues in operation until the operator depresses the "top stop" pushbutton **19.**

When the operator depresses the "top stop" pushbutton **19,** switch **PB6c** is opened, thereby de-energizing relay coil **1CR.** When relay coil **1CR** is de-energized, contact **1CR7** opens, but the press continues to run since coils **2CR** and **4CR** remained locked in via contacts **4CR14, 4CR15,** and **2CR8,** and switches **1CLS6** and **SS5.** The opening of the contact **1CR7** puts the relay coils **2CR** and **4CR** under control of the top stop switch **1CLS6,** since both coils **2CR** and **4CR** are now energized via switch **1CLS6.** Consequently, when the press ram passes the 320° point in its stroke cycle, the resultant opening of switch **1CLS6** de-energizes both coils **2CR** and **4CR** and solenoids **S1** and **S2** so that the press stops at the top of the ram stroke as in the "single stroke" mode.

When the press ram reaches the end of its stroke cycle, the switch **1CLS6** closes again so that the circuit is ready for the nest cycle operation. In the event that the switch **1CLS6** were to fail to close due to a malfunction, no further operation of the press is possible except in the "inch" mode. Another safety feature is that if the relay coil **4CR** does not drop out, due to a malfunction, contact **4CR6** remains open, so that no further operation of the press is possible.

As can be seen from the foregoing detailed description, the control system provided by this invention is inherently safer and more foolproof than systems that have been available in the past, in that it serves to bring the press to a stop at the end of a cycle while minimizing the opportunities provided to the press operator to maintain the system in operation by manipulation of the controls. The present control system guards against sticking of relays and prevents the operator of the press from counteracting the sticking of relays by the by the expedient of holding down run buttons. The system also prevents switching from one mode to the other in the event of a malfunction in the first mode, and provides increased safety when the press is operated in the continuous mode, insuring that the press will not be operated continuously except as a result of predetermined and essential action on the part of the operator. This control system makes increased use of fail safe techniques in that failure of a component not only results in a safe condition of shutdown, but also redundant circuit elements are automatically and continuously checked either during or after each press operation. All of these safety features are provided in a control system which is also conveniently switchable to provide the various modes of operation, which provides a high level of flexibility, and which is easily and highly economical as well as being easily and quickly serviced.

We claim as our invention:

1. An automatic control system for a power press having a vertically reciprocating ram, said control system comprising the combination of a selector switch having an inoperative position and a first operative position for enabling movement of the press ram through

one cycle of reciprocating movement, a second operative position for enabling movement of the press ram through successive increments of its reciprocating cycle according to manually initiated command signals, and a third operative position for enabling movement of the press ram continuously through repetitive cycles of reciprocating movement, reset means operatively connected to said selector switch and including a manually operated actuator for enabling movement of the press ram when said selector switch is in any one of its three operative positions, a pair of spaced apart, manually operated press actuators operatively connected to said selector switch and to said reset means and having operative positions for initiating movement of the press ram when said selector switch is in any one of its three operative positions and when said reset means is actuated, and means responsive to the switching of said selector switch from one of its operative positions to another for stopping movement of the press ram and rendering said press actuators inoperative until said reset means is acutated again.

2. An automatic control system as set forth in claim 1 which includes single stroke mode control means responsive to movement of the press ram and operatively connected to said selector switch for automatically stopping the press ram at the end of one cycle of reciprocating movement when said selector switch is in said first operative position regardless of whether said press actuators are operated at the end of said cycle.

3. An automatic control system as set forth in claim 2 which includes automatic resetting means responsive to movement of the press ram for automatically acutating said reset means at the end of each ram cycle so that successive single strokes of the ram can be effected by operating said press actuators without manually actuating said reset means between successive ram strokes.

4. An automatic control system as set forth in claim 3 which includes second single stroke mode control means responsive to movement of the press ram and operatively connected to said selector switch for automatically stopping the press ram at the end of one cycle of ram movement when said selector switch is in said first operative position regardless of whether said press actuators are in their operative positions at the end of said cycle, said second single stroke mode control means also being responsive to a malfunction of said first single stroke mode control means for rendering said reset means ineffective so that further movement of the press ram is prevented until the malfunction of said first single stroke mode control means is corrected.

5. An automatic control system as set forth in claim 4 which includes a third single stroke mode control means for rendering said press actuators inoperative in response to a malfunction of said second single stroke mode control means so that further movement of the press ram is prevented until the malfunction of the second single stroke mode control means is corrected.

6. An automatic control system as set forth in claim 2, which includes control means responsive to movement of either of said press actuators away from its operative position for stopping ram movement and rendering both press actuators inoperative until both of said press actuators are concurrently moved away from their operative positions and then concurrently returned to their operative positions.

7. An automatic control system as set forth in claim 1 which includes control means responsive to movement of either of said press actuators away from its operative position for stopping ram movement and rendering both press actuators inoperative until both of said press actuators are concurrently moved away from their operative positions and then concurrently returned to their operative positions.

8. An automatic control system as set forth in claim 7 which includes a continuous mode control means responsive to movement of the press ram and including a manual actuator for automatically repeating successive cycles of ram movement only when said manual actuator is moved to an operative position, when the press ram has traversed a selected initial portion of the first half cycle of ram movement, and when said selector switch is in said third operative position.

9. An automatic control system as set forth in claim 1 in which said press acutators initiate movement of the press ram, via press operating control means, and which includes means for rendering said press actuators inoperative in response to a malfunction of said press operating control means so that further movement of the press ram is prevented until the malfunction of the press operating control means is corrected.

10. An automatic control system as set forth in claim 1 which includes means responsive to movement of the press ram and operatively connected to said press actuators for automatically stopping ram movement in response to movement of either of said press actuators away from their operative positions during a selected initial portion of the first half cycle of ram movement, and means operatively connected to said selector switch and responsive to movement of the press ram for automatically continuing movement of the press ram through the remaining portion of the ram cycle regardless of the position of said press acutators, when said selector switch is in said first operative position.

11. An automatic control system as set forth in claim 1 which includes means for de-energizing the entire control system in response to a grounding of one of said press actuators or the wiring associated thereto.

12. An automatic control system as set forth in claim 1 which includes a continuous mode control means responsive to movement of the press ram and including a manual actuator for automatically repeating successive cycles of ram movement only when said manual actuator is moved to an operative position, when the press ram has traversed a selected initial portion of the first half cycle of ram movement, and when said selector switch is in said third operative position.

13. An automatic control system as set forth in claim 12 which includes a top stop control means having a manual acutator for automatically stopping the press ram at the end of a cycle in response to movement of said actuator to an operative position at any time during said cycle.

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