

Jan. 4, 1966

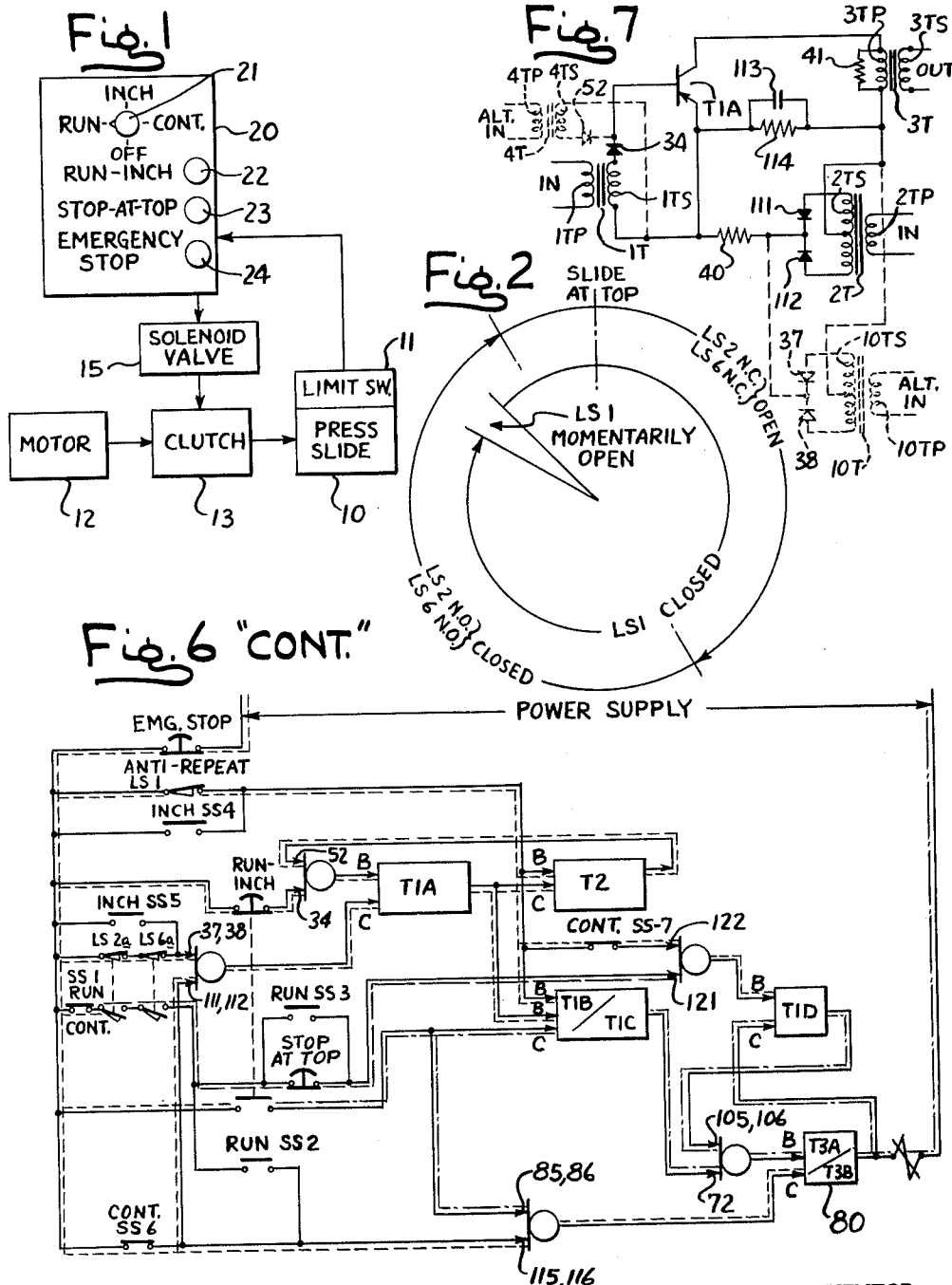
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3,227,255

CONTROL FOR POWER PRESS

Filed Jan. 29, 1962

4 Sheets-Sheet 1



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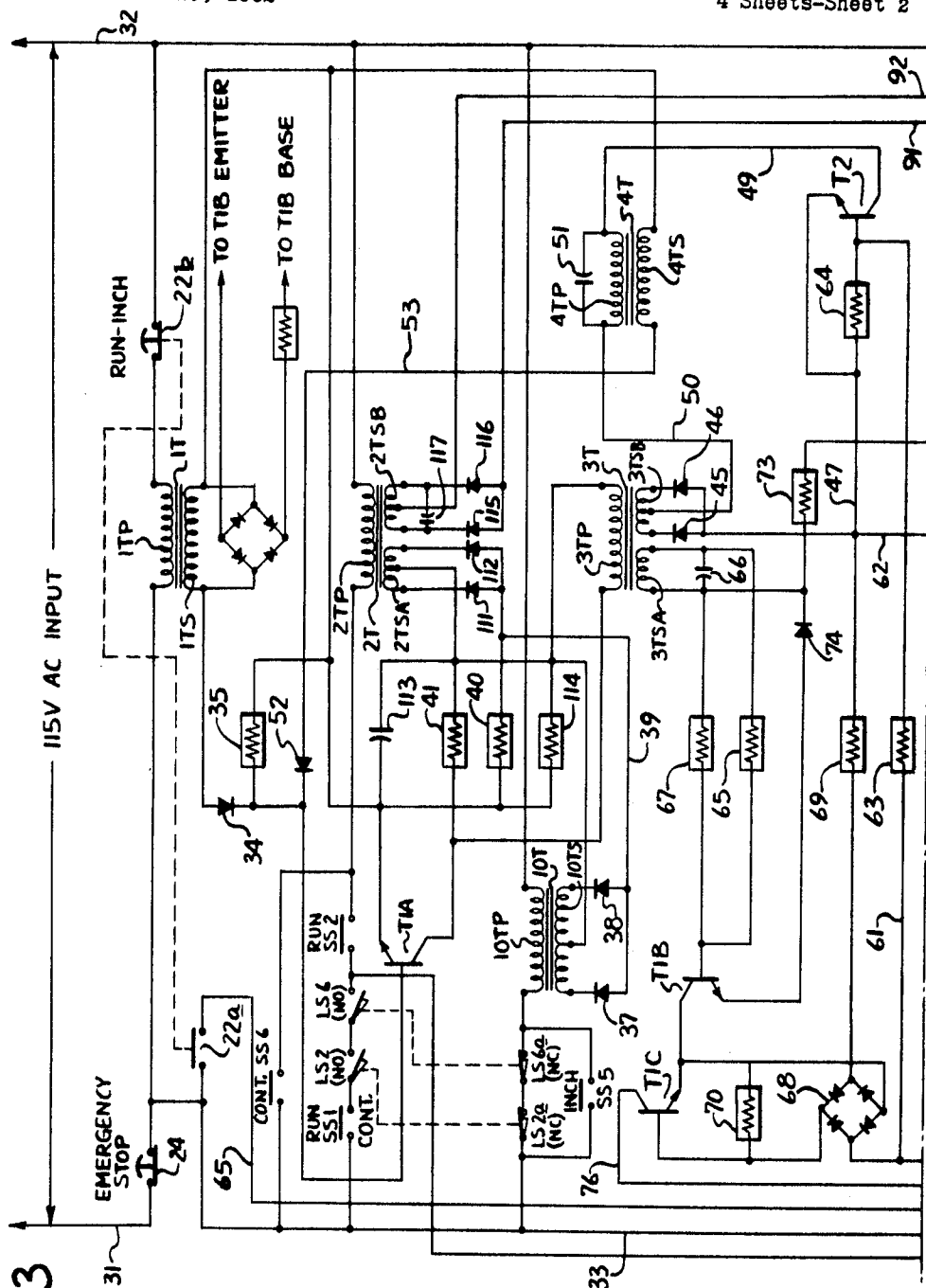
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4 Sheets-Sheet 2



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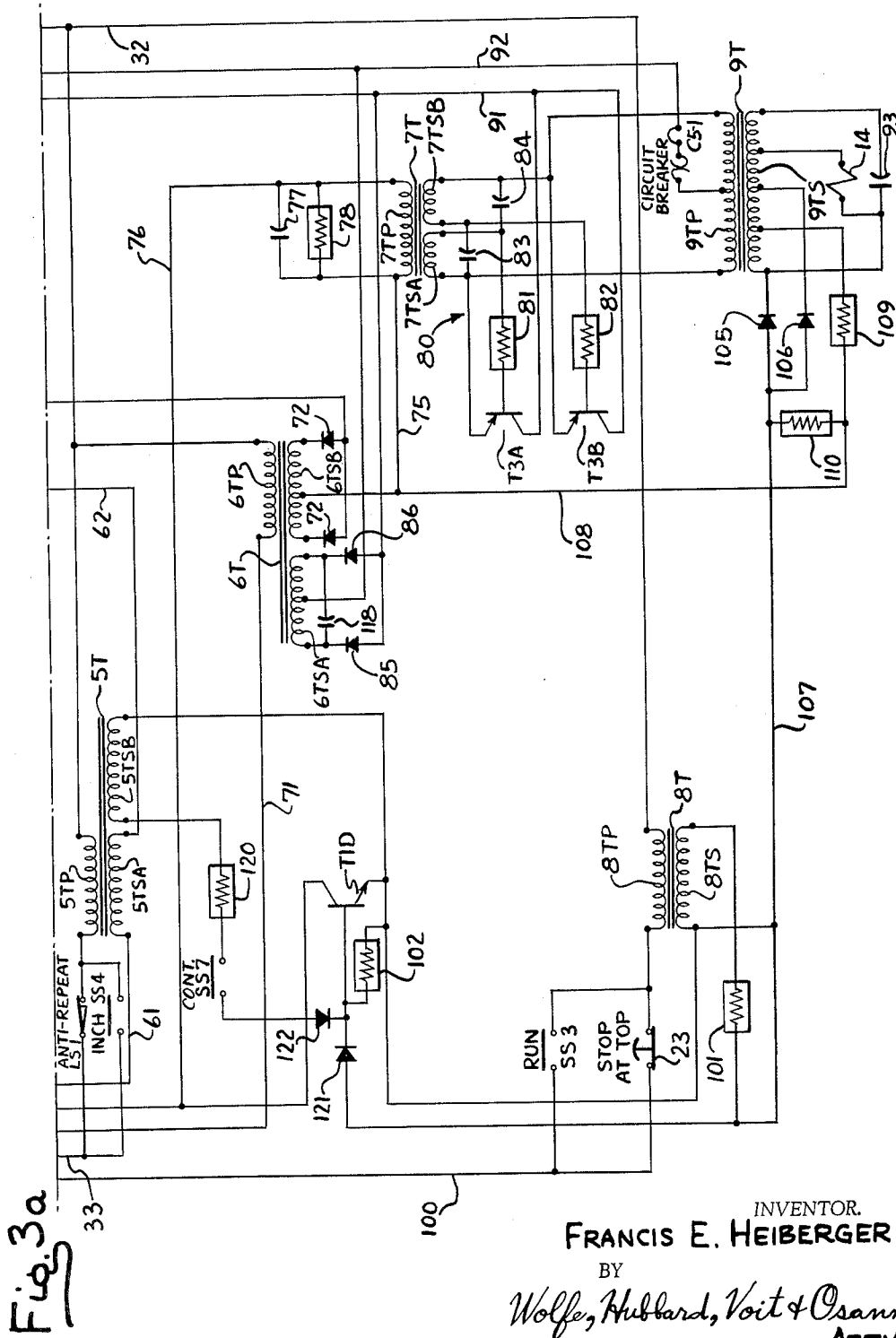
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CONTROL FOR POWER PRESS

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Jan. 4, 1966

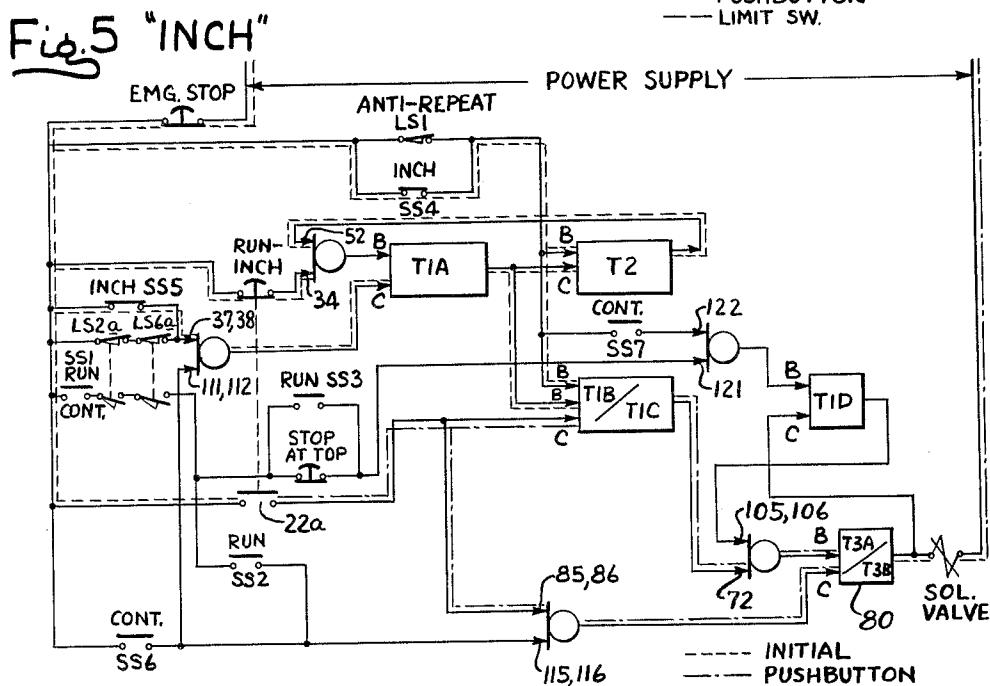
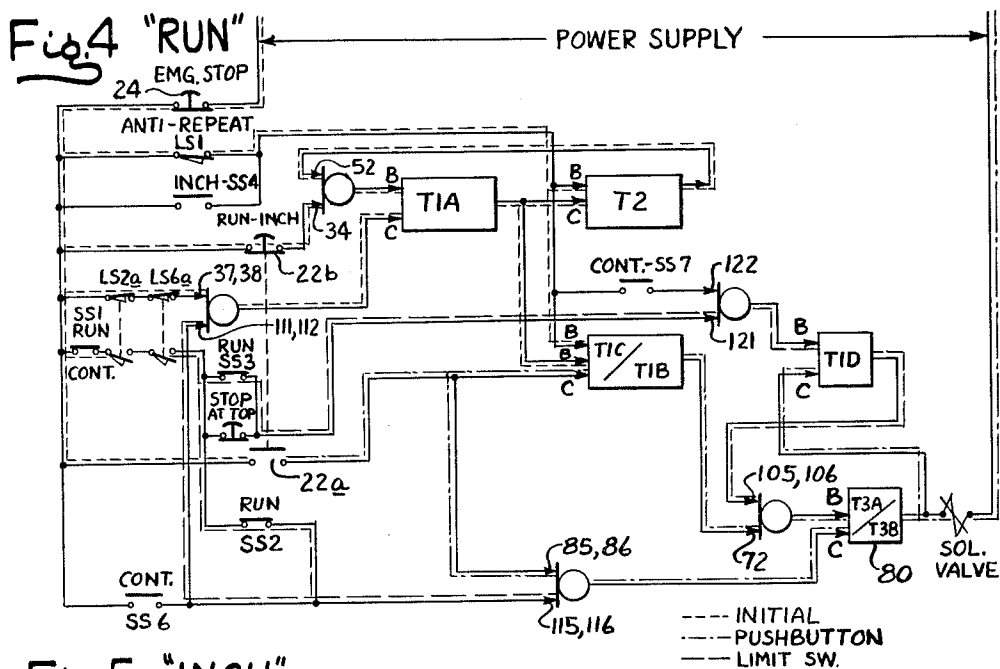
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4 Sheets-Sheet 4



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3,227,255

CONTROL FOR POWER PRESS

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11 Claims. (Cl. 192-142)

The present invention relates to an arrangement for controlling the operation of a power press and which permits various modes of press operation with a high degree of safety and reliability.

It is conventional in power presses to provide several modes of operation usually referred to as "run," "inch" and "continuous," with the modes being selectable by a selector switch on the control panel. In the "run" mode pressing the run pushbutton causes the slide to begin to move downwardly from its upper position. Dual pushbuttons are usually employed so that both hands of the operator must be kept in contact with the pushbuttons until near the bottom of the stroke at which time a "run" limit switch takes over control to complete the stroke and to restore the slide to its upper position. A separate "anti-repeat" limit switch is provided which is automatically actuated toward the end of the cycle in order to insure that the slide will stop at the end of the cycle even though the operator maintains the pushbuttons depressed. That is, separate actuations of the pushbuttons are required to initiate each successive cycle. The anti-repeat limit switch therefore tends to insure against inadvertent "double cycling" by a careless operator.

In the "inch" mode of operation the control circuits are set up so that the press rotates only during the time that the operator's hand is in contact with the pushbutton. This mode of operation is used to advance the press slide in steps, a little at a time, especially during adjustment or inspection.

In the "continuous" mode, once action is initiated by depressing the pushbuttons, the press continues to operate or recycle until it is intentionally turned off, usually by actuating a "stop at top" pushbutton.

In spite of the taking of elaborate precautions to interlock the various functions, conventional control circuits are subject to occasional malfunction by failure of critical elements, particularly the electrical relays. When this occurs there is a severe hazard to the operator and to the machine. Moreover, in a conventional circuit it is possible for short circuits, failure of relay contacts or the like to set up a potentially hazardous condition which may go undetected for long periods of time until, when least expected, a combination of circumstances occurs to precipitate the final failure.

Accordingly, it is an object of the present invention to provide an improved control circuit for a power press which is safe and reliable even when operated over long periods of time and which avoids the hazards associated with the use of relays and contactors. It is another object of the present invention to provide a control circuit for a power press which is "fail safe" in operation so that any failure of critical parts results simply in turning off the press thereby avoiding any possibility of a hazardous condition for the operator or the press itself. More specifically, it is an object of the present invention to provide a control circuit for a power press which employs passive switching elements in the logic circuitry in the form of transistors which are reliable and long lived but in which any transistor failure, either by reason of a short circuit or open circuit, results in the automatic turning off of the power bringing the press to an immediate stop so that the difficulty may be remedied.

It is another object of the present invention to provide

a control circuit for power press which is flexible in operation having safety features in the "inch" and "continuous" modes of operation as well as the "run" mode and which may be readily changed from one mode to another as required in practical press operation.

It is an object in one aspect of the invention to provide a control circuit for a press which is fail safe and substantially foolproof but which may be made for a cost which is comparable to that of conventional control systems subject to conventional failures. It is moreover an object of the invention to provide an improved control arrangement for a press which is compact, which is substantially proof against shock and vibration and which requires substantially no maintenance, enabling the press control panel to be installed in any orientation and in any convenient position upon the press thereby reducing installation cost to a minimum.

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

FIGURE 1 is a block diagram showing a control panel of the type used with the present invention.

FIG. 2 is a diagram showing the periods during which the cam or limit switches are open and closed during a complete cycle of the present slide.

FIGS. 3 and 3a comprise a schematic circuit diagram of a control arrangement employing the present invention.

FIG. 4 is a diagram showing the control lines which are energized during a typical "run" cycle.

FIG. 5 is a diagram showing the lines which are energized during a typical "inch" cycle.

FIG. 6 is a diagram showing the lines which are energized during "continuous" operation.

FIG. 7 is a schematic diagram showing the various inputs to one of the transistor stages and to bring out the fail-safe nature of the circuitry.

While the invention has been described in connection with a preferred embodiment, it will be understood that I do not intend to be limited to the embodiment shown but intend to cover the various alternative and equivalent arrangements included within the spirit and scope of the appended claims.

The present invention is particularly applicable to large power presses but may, if desired, be applied to any type of press having a reciprocating cycle. Consequently, the construction of the press itself has not been illustrated in the drawings; instead, the press slide has been indicated diagrammatically at 10 coupled to a limit switch assembly 11 and driven by a motor 12 through a clutch 13. The clutch, it will be understood, has an associated brake which is coupled to it for alternative energization. For engaging and disengaging the clutch a solenoid control valve 15 is employed which is under the control of a panel or control station indicated at 20, including a control circuit to be described in some detail and which is under the control of electrical switches and the limit switch assembly 11. Thus, in a practical case, there is provided a selector switch 21, a "run-inch" pushbutton 22, a "stop at top" pushbutton 23 and an emergency stop pushbutton 24. The operator selects the desired mode of operation on the selector switch and thereafter controls the operation by pressing one or more of the pushbuttons. It will be understood that the control station is diagrammatic as shown in FIG. 1 and that the actual pushbuttons, particularly the run-inch pushbutton, may be located in the operating position and may consist of a pair of pushbuttons required to be simultaneously pressed by the two hands of the operator, thereby to insure that the operator has both hands clear of the slide. Also, if desired, foot-operated switches may be provided. This is a matter well within the skill of the art.

Prior to discussing the control circuit, reference may be made to the phase diagram, FIG. 2, which shows the periods that the limit switches are open and closed during a single revolution of the crank shaft driving the slide. Within the switch assembly 11, and set forth in the wiring diagram in FIGS. 3, 3a, there is provided an "anti-repeat" limit switch LS1 which is normally closed but which is open for a short space of time, i.e., over an arc of about 20°, as the slide completes the upper portion of its stroke. A "run" limit switch having sections LS2 and LS6 is closed before the bottom of the slide stroke, for example, at an angle of 170° of the crank shaft and is opened again prior to the time that the slide is returned to its fully upraised position.

The limit switches LS1, LS2 and LS6 may be in the form of cam operated switches operated by a cam on the crank shaft. However, I prefer to use a special static switch assembly having no moving parts and responding simply to the condition of proximity between relatively moving elements. Such "proximity" limit switch arrangement is discussed in my copending application Ser. 220,458 filed August 30, 1962.

The present circuit is powered from power lines 31, 32 connected to the regular commercial A.-C. supply. The emergency stop button 24 is, as shown, in series with the line 31 and normally closed so that as long as the stop button is not depressed power is applied to a supply bus 33. Connected between the supply bus and line 32 is a transformer 1T having a primary winding 1TP and a secondary winding 1TS. In series with the primary is a set of normally closed contacts 22b of the run-inch pushbutton. Connected in series with the secondary winding is the base circuit of a transistor T1A which, because it performs a memory function, may be referred to as a "memory" transistor. For purposes of isolation a diode 34, forming one leg of an "or" gate, is interposed in the base circuit. The transistor is provided with an input resistor 35 which bridges the base and emitter contacts.

For initially supplying the collector circuit of the transistor T1A, with the slide at the top of the press and before it begins its downward movement, a transformer 10T is connected from the bus 33 to the line 32 via normally closed contacts LS2a, LS6a on the limit switch LS2, LS6. Diodes 37, 38 connected in the output circuit of the transformer provide full wave rectification. The diodes are connected to the emitter of the transistor T1A via a line 39 and series resistor 40. The collector or output circuit is completed through the primary winding of a transformer 3T which serves as the output transformer for the transistor T1A. Arranged in parallel with the primary winding of the transformer 3T is a resistor 41 to minimize ringing. It will be apparent that with the transformer 1T energized across the line to provide a base input signal and the transformer 10T energized to provide energization for the collector, an A.-C. output signal will exist at the secondary windings of the transformer 3TP. The circuit just described possesses a novel "fail-safe" feature which is also employed in the other transistor circuits forming a part of the present control arrangement and as will be discussed in detail at a later point. It will suffice for the present to say that an output signal is produced at the secondary windings of the output transformer 3T only when control signals are simultaneously applied to the transistor and collector circuits for operation of the clutch on the press through the associated circuitry, and failure of the transistor, either by short circuiting or open circuiting, is incapable of producing an output signal.

In carrying out the present invention, it is desirable to maintain the transistor T1A energized even though the transformer 1T is turned off by opening of the normally closed contacts 22b when the run-inch pushbutton is depressed. This function is provided by a loop or "holding" transistor T2 having a collector circuit which is energized by the secondary winding 3TSB of the first

transistor output transformer 3T. The output voltage of the latter is rectified by diodes 45, 46 feeding a line 47 which is connected to the emitter of the transistor. The collector circuit of the transistor is completed through a loop output transformer 4T via lines 49, 50. Bridged across the primary of the transformer 4T is a capacitor 51 to improve the wave shape. The secondary winding of the loop output transformer is fed to a diode 52 via a loop line 53, the diode being connected directly to the base terminal of the memory transistor T1A. It will be apparent then that the diodes 34, 52 together form an "or" gate for alternatively energizing the base.

Attention may next be given to the means for energizing the base of the loop transistor T2. The current for accomplishing this is derived from a transformer 5T, the primary of which is connected in series with the anti-repeat limit switch LS1 across lines 32, 33. With the press slide at the uppermost position the transformer 5T is energized. The output voltage from the secondary winding 5TSA is applied to the base-emitter circuit of the transistor T2 via lines 61, 62 respectively. Interposed in series with the base circuit is a resistor 63 and the transistor is, in addition, provided with an input shunting resistor 64.

It will be apparent, then, that with the base circuit energized by the transformer 5T and the collector circuit energized by the transformer 3T, a signal will be generated in the loop transformer 4T to serve as an alternate source of supply, through diode 52, to the base of the transistor T1A. Under initial conditions before the run-inch pushbutton is depressed, input signals are applied to the base of the transistor through both legs of the "or" gate 34, 52.

When the run-inch pushbutton is depressed, the breaking of the contacts 22b turns off the transformer 1T thereby removing one of the two inputs, that form diode 34, to the base of transistor T1A. However, the transistor continues to conduct because of the loop signal received through the diode 52.

In carrying out the present invention an output transistor stage is provided having a base circuit which is energized by the memory transistor T1A and a collector circuit which is energized by the making of the normally open contacts 22a on the run-inch pushbutton. In the present instance the output transistor stage consists of two transistors, T1B and T1C, having their collector circuits connected in series with one another and having separate means for energizing the base circuits in order to insure proper phasing of the output and to overcome any phase shifts which have occurred in the control signal which is fed through the circuit transformers. Turning attention first to the means for supplying the base of the transistor T1B it will be noted that the base is fed from the secondary winding 3TSA of the output transformer 3T for transistor T1A. The base circuit is completed through a series resistor 65. Arranged in parallel with the base circuit is a capacitor 66 and resistor 67. As long as the transistor T1A is turned on the base of transistor T1B is energized. For the purpose of supplying the companion transistor T1C with full waves of current substantially in phase with the current in the supply line, a full wave rectifier 68 is provided which is connected across the secondary of the transformer 5T and with a series resistor 69 interposed. The output terminals of the rectifier 68 are connected directly to the base and emitter electrodes of the transistor T1C with a shunting resistor 70 in parallel therewith.

Having provided for energizing both of the base circuits, attention may be given to the means for energizing the series-connected collector circuits of the transistors T1B, T1C. For this purpose a transformer 6T is provided having its primary winding connected in series with the normally open contacts 22a of the run-inch pushbutton via a line 71. For rectifying the output of the transformer 6T diodes 72 are provided feeding a line connected via a resistor 73 and diode 74 to the emitter elec-

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trode of the transistor T1B. The diode 74 which is of the silicon type, serves to provide back bias and to improve the response time. A transformer 7T provides the output element for the collector circuit of transistors T1B, T1C. Thus a connection 75 is made between the secondary of the transformer 6T, which supplies collector current, and the primary winding of the winding 7T. The other end of the primary winding is connected to the collector element of the transistor T1C via a line 76. Arranged in shunt with the primary winding of the transformer 7T is a capacitor 77 and resistor 78 to improve the wave shape and prevent ringing. The emitter of the transistor T1C is, as shown, directly connected to the collector of the transistor T1B.

To sum up, when the run-inch pushbutton is depressed the transformer 6T is energized to supply rectified current to the output circuit of the output transistor stage T1B, T1C. The base circuit of the transistor T1B is energized by the transformer 3T in the output circuit of the transistor T1A. The latter transistor remains on by reason of the loop circuit previously described even though the normally closed contacts 22b on the run-inch pushbutton are opened. The base circuit of the transistor T1C, provided for phasing purposes, is energized through the transformer 5T which is connected to the input line. Thus, when the run-inch pushbutton is depressed, all of the conditions are satisfied for current to flow through the primary winding of the output transformer 7TP. The output signal from the transformer 7T, as will be seen, serves to energize a push-pull power amplifier stage which directly feeds the winding of the solenoid 15 thus energizing clutch 13 of the press.

Consequently detailed attention may be given to the power output stage indicated at 80. The transformer 7T has two output windings which are connected to the base circuits of power transistors T3A and T3B respectively connected in push pull. The latter have input resistors as indicated at 81, 82. Cross-connected capacitors 83, 84 are provided for the purpose of improving the push pull action. Improvement in symmetry is desirable since the primary of the transformer is supplied with half waves of A.-C.

In order to supply current to the collector circuits of the power transistors 3TA, 3TB, two alternative sources are provided, one operating during the time that the run limit switches are "open" and the other time that the limit switches are "closed." Immediately after the run-inch pushbutton is depressed and as the press slide begins to move, the limit switches LS2, LS6 are not yet closed and hence current is supplied from the transformer 6T which is energized, as previously noted, through the run-inch pushbutton. Thus, the secondary 6TSA of the transformer is provided with rectifiers 85, 86 which are connected to a pair of power amplifier supply lines 91, 92. The line 91 is connected directly to the collector elements of the two power transistors. The circuit is completed from line 92 through the primary of a final power output transformer 9T. The outer ends of the primary winding of the transformer 9T are respectively connected to the emitter elements of the power transistors. It will be apparent, then, that with the bases of the transistors 3TA, 3TB made alternately conducting and with fully rectified A.-C. being applied to the collectors, the two transistors will operate in the well known push-pull fashion to set up an alternating voltage in the secondary of the transformer 9T. The winding of the solenoid 15, being connected across a portion of the secondary of the transformer 9T, and thereby energized with alternating current, turns on the clutch 13 so that the press shaft begins to rotate. The associated capacitor 93 which is connected across the output of transformer 9T serves to further improve the symmetry of the output wave and to minimize peak voltages.

It is necessary during the initial portion of such rotation for the operator to keep his hand on the run-inch

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pushbutton since if the contacts 22a thereon are opened transformer 6T will immediately be deenergized thereby deenergizing the collector circuit of the transistors T1B and T1C and the power output transformer 7T. This deenergizes the bases of the power output transistors T3A, T3B. Moreover, deenergization of transformer 6T deenergizes the lines 91, 92 which supply the collectors of the output transistors further insuring that the press will come to an immediate halt.

In carrying out the present invention novel means actuated by the run limit switches LS2, LS6, are provided for "taking over control" when the slide approaches the lower end of its stroke so that the manual pushbutton may thereafter be released for automatic completion of the cycle. This is accomplished by providing a "run" transistor energized by the run limit switches and which provide an alternate source of energization for the primary winding of the output transformer 7T. The run transistor, indicated at T1D, is provided with a transformer 8T for energizing the base circuit whenever the press is in the run mode and whenever the run limit switches are closed. Thus it will be noted that the primary winding of the transformer 8T is energized via a line 100 (the selector switch contacts SS1 and SS3 being closed) from the output side of the limit switch LS6. The secondary of the transformer 8T is connected to the base-emitter circuit of the transistor T1D via series resistor 101, and an input or shunting resistor 102 is connected across the transistor input as shown.

Turning attention to the collector circuit of the transistor T1D, it will be noted that the collector is directly connected to the right hand primary terminal of the transformer 7T through the line 76. Current is supplied to the emitter-collector circuit from the secondary winding of the final output transformer 9T, full wave rectification being provided by diodes 105, 106. The emitter of the transistor T1D is connected to the diodes via a line 107, and the circuit to the remaining side of the transformer 7T primary is completed by the line 108. Associated with the diodes is a series resistor 109 and a paralleled or bleeder resistor 110.

To summarize with respect to the "run" transistor T1D, closure of the "run" limit switches energizes the transformer 8T which energizes the base circuit. Current to energize the collector circuit is already available since transformer 9T has been previously energized by pressing the run-inch pushbutton as set forth in the above paragraphs. This satisfies the condition for conduction in the transistor T1D so that the output circuit thereof supplies voltage to the primary of the transformer 7T to maintain the solenoid 15, and hence the clutch of the press, energized. As long as the operator maintains his hand on the run-inch pushbutton, transformer 6T continues to be energized so that two separate input voltages are applied to the transformer of the primary 7T. The operator is subsequently free to release the run-inch pushbutton under the run condition without stopping the press. Thus when the contacts 22a are broken deenergizing the line 65, the transformer 6T is turned off. This cuts off current flow in the line 68 which feeds the collector circuit of the output transistors T1B, T1C. As a result these transistors are turned off so that the voltage, initially applied to the primary of the transformer 7T when the pushbutton was depressed, is removed. However, as noted, the transformer 7T continues to be energized by the run transistor T1D.

Deenergizing the transformer 6T also has the effect of turning off the initial source of voltage for the supply lines 91, 92 which feed the collector circuits of the power transistors. Moreover, closing of the normally open contacts on the limit switches LS2, LS6 is accompanied by opening of the contacts LS2a and LS6a thereof which turns off the transformer 10T. In order to provide an alternate source of supply for the collector circuit of the power transistors T3A and T3B and in order to provide

an alternate source for the collector circuit of transistor T1A following engagement of the run limit switches, a transformer 2T is provided. The primary of the transformer is connected across the supply lines 32, 33 via the selector switch elements SS1 and SS2 (which are closed in a run condition) and the limit switches LS2, LS6. The transformer 2T has two secondaries, 2TSA and 2TSB. The voltage of the first secondary winding is fully rectified by a pair of diodes 111, 112 and the output is connected in parallel with the line 39 from the previously energized transformer 10T. In order to bridge the gap between the time that the transformer 10T is turned off and the transformer 2T is turned on, a capacitor 113, shunted by a resistor 114, is employed providing a sufficiently long time constant so that there is no interruption in the current flow through the collector circuit of the transistor. Similarly, the voltage from the second secondary winding is rectified by diodes 115, 116 for the purpose of energizing the lines 91, 92 leading to the power output stage when the transformer 6T is turned off. Capacitors 117, 118 are provided in the circuits of transformers 2T and 6T to improve wave forms and to suppress line transients.

By way of summary of the above, it will be noted that even though the run-inch pushbutton is released after the run limit switches "take over," current continues to be supplied to the power stage, the loop circuit through the loop transistor T2 continues to be effective, and the transistor T1A continues to be energized.

Thus the clutch continues to be energized as long as the run limit switches are closed, i.e., as long as the run transistor T1D is energized by the transformer 8T. However, means responsive to the opening of the anti-repeat limit switch LS1 are provided for opening the loop circuit around transistor T1A to insure that the run-inch pushbutton must be reenergized to initiate a subsequent cycle of press operation. To this end the anti-repeat switch is inserted in series with the primary winding of the transformer 5T which supplies the base circuit of the loop or holding transistor T2. It will be apparent, then, that when the switch LS1 opens momentarily (see FIG. 2), the base circuit of transistor T2 is momentarily de-energized interrupting conduction in the collector circuit thereof which interrupts the input to the base circuit of the memory transistor T1A. The latter transistor then becomes non-conductive, deenergizing the primary of transformer 3T which supplies the collector circuit of the transistor T2. Thus the opening of the switch LS1 has deenergized both the base and collector circuits of the transistor T2.

Whether the loop circuit is reestablished upon reclosure of switch LS1 depends upon whether the run-inch pushbutton is or is not release. If released, the making of contacts 22b thereon energizes the base of transistor T1A which reenergizes the collector circuit of transistor T2 to turn on the latter and complete the loop. This results in the energization of the base of T1B. However, the collector remains deenergized so there is no output from the transistor T1B, T1C to output transformer 7T. However, 7T remains energized by run transistor T1D as long as the run limit switches LS2, LS6 are closed.

A short time later when the limit switches LS2, LS6 reopen, this results in deenergizing the line 100 supplying the transformer 8T. This turns off the base circuit of the run transistor T1D which removes voltage from the line 108 supplying the primary of the transformer 7T. The latter is effective to turn off the power amplifier and deenergize the solenoid so that the press comes to rest with the slide at the top.

In the above discussion it has been assumed that the run-inch pushbutton has been released. However, the result, i.e., stopping at the top, would be the same if the operator had maintained the pushbutton in the depressed condition. Thus, it will be recalled that two conditions are necessary for the output transistors T1B, T1C to conduct: Current must be supplied to the base and also

to the collector. If the operator maintains the pushbutton depressed the transformer 6T will, it is true, remain energized and the collector circuit of the transistors T1B, T1C will remain energized. However, this is not sufficient to produce conduction in the latter transistors since the base of transistor T1B is, under such circumstances, deenergized, transistor T1A being turned off. Transistor T1A has been aptly referred to as a "memory" transistor when used in cooperation with the loop circuit and anti-repeat limit switch LS1. By reason of its non-conduction at the time that the run limit switches are opened, it has "remembered" that the run-inch pushbutton has not been released so that the press is brought to a stop at the top of the stroke requiring the run-inch pushbutton to be again depressed to initiate the subsequent press cycle.

In accordance with one of the aspects of the present invention, positive "dropout" is provided both in the run-inch control circuit and also in the alternative run limit switch circuit. Thus, in the period prior to engagement of the run limit switches LS2, LS6, pressing the emergency stop button 24 even momentarily serves to break the loop circuit around the transistor T1A by causing momentary non-conduction in the transistor T2. As a result, the press will not restart by releasing the emergency stop button, even though the run-inch button is continually held down. The run-inch button under such conditions must be momentarily released and reapplied in order to energize the clutch. In the event that the run limit switches LS2, LS6 are closed at the time that the emergency stop button 24 is depressed, this will have the effect of deenergizing the solenoid supply at the output of the power amplifier which also furnishes collector current for the run transistor T1D. Releasing the emergency stop button will be ineffective to restore collector current to the run transistor T1D and hence the transistor will remain deenergized and ineffective to apply power to the solenoid until such time that the run-inch pushbutton is again depressed. Accordingly, it is impossible, under any condition, to operate the emergency stop button as a jogging or inching switch.

Résumé of "run" condition

While the operation of the press control system in the "run" condition normally employed will be apparent from the above description, the operation may be more graphically visualized by reference to the diagram set forth in FIG. 4. Here the condition of the circuit is shown by indicating which of the various lines are conductive during the three main conditions, i.e., the initial condition is indicated by the dotted lines, the condition with the run button depressed is indicated by the dot-dash lines and the condition following closure of the run limit switches is indicated by the dashed lines. With the selector switch in the "run" mode contacts SS1, SS2 and SS3 are closed. Initially, and with the normally closed contacts 22b closed, the base of transistor T1A is energized. The collector is also energized through the normally closed contacts LS2a and LS6a on the run limit switches. Conduction in transistor T1A serves to energize the collector of transistor T2 and the base of output transistor T1B. The base of transistor T2 is energized through the anti-repeat limit switch so that the transistor T2 is turned on closing a loop circuit about transistor T1A.

When the run-inch pushbutton is pressed, conduction takes place in the dot-dashed connections. Collector current is supplied to the output transistors T1B, T1C turning these transistors on thereby energizing the power amplifier 30 stage and solenoid 15. When the limit switches LS2 and LS6 close, toward the bottom of the stroke, the base circuit of the run transistor T1D is energized, the collector circuit having been previously energized along with the solenoid, so that the transistor T1D, serving as an alternate source for transformer T7, takes over control to maintain the solenoid energized. Consequently the press will continue to run even though the run-inch pushbutton is

released. However, momentary opening of the anti-repeat limit switch LS1 interrupts the flow of base current to the transistor T2 opening the loop circuit about the transistor T1A so that when the run limit switches LS2 and LS6 again open, the press will come to a halt at the top of the stroke.

Operation of press in "inch" condition

To establish this mode of operation (FIG. 5) the selector switch is turned to the "inch" mode which opens the run switches SS1, SS2 and SS3 and closes the contacts SS4 and SS5. Opening the contacts SS1 and SS2 has the effect of disabling the transformer 2T while opening the contacts SS3 has the effect of removing the jumper from around the "stop at top" switch 23. Closing switch SS4 bridges the anti-repeat switch LS1 so that the anti-repeat feature is, in effect, removed from the circuit during "inch" operation. Closing the switch SS5 bridges the normally closed contacts LS2a, LS6a of the run limit switch thereby placing transformer 10T permanently in the circuit for energization of the collector of the transistor T1A.

With the selector switch in the above position and prior to pressing the pushbutton 22 the transformer 1T is turned on which energizes the base of transistor T1A. The collector circuit of the transistor is continually energized as a result of closure of contacts SS5. With the transistor T1A conducting, collector current is supplied to the transistor T2. The base of the transistor is also energized through the contacts SS4 and the closed (but ineffective) contacts of the anti-repeat limit switch LS1. Consequently the transistor T2 conducts, completing the loop circuit about the transistor T1A. With the transistor T1A turned on, the base circuit of the output transistor T1B is energized. The output transistor stage is ineffective since the collector circuit is not energized. The latter waits the closure of contacts 22a which supply collector current to the transistors T1B, T1C.

When the run-inch pushbutton, operating in its inch mode, is depressed, closure of the contacts 22a energizes the transformer 6T thereby energizing the collector circuit of the output transistor stage T1B, T1C, and applying voltage to the primary winding of the transformer 7T to turn on the power amplifier. This energizes the solenoid valve which turns on the press clutch so that the press slide begins to move. The opening of the contacts 22b on the run-inch switch does not affect the situation because of the loop circuit which has been established about the memory transistor T1A. The press thus continues to run as long as the run-inch button is depressed. When the button is released, opening of the contacts 22a deenergizes the transformer 6T which cuts off collector current from the output transistors T1B, T1C thereby turning off the current stage. The run limit switch is ineffective to "take over" control since opening of the selector switch contacts SS1 has disabled transformer 8T which supplies base current to the run transistor T1D.

"Continuous" operation of press

In this mode of operation, momentary pressing of the run-inch button serves to initiate rotation of the press shaft and means are provided for thereafter constantly energizing the transistor T1D so that it continues to apply voltage to the transformer 7T which feeds the power output stage and its connected solenoid. Once energized in this mode the press will continue to cycle endlessly until the "stop at top" pushbutton 23 is pressed to bring the press to a stop with the slide at the top of the stroke.

Under the initial conditions and before the run-inch pushbutton is depressed the setting of the selector switch to the continuous mode accomplishes the following: Contacts SS1 are closed thereby connected the transformer 8T, which supplies the run transistor T1D with base current in series with the run limit switch LS2, LS6. Contacts SS2 are opened and contacts SS6 are closed thereby energizing the primary of the transformer 2T which supplies

the collector circuit of the transistor T1A and also the collector circuit of the transistors in the power amplifier. Contacts SS4 and SS5 associated with the "inch" function are opened. For the purpose of supplying the transformer 8T which energizes the base of the run transistor T1D during the time that the n. o. run limit switch contacts LS2 and LS6 are open, contacts SS7 on the selector switch are closed to connect an auxiliary base supply to the run transistor T1D. Such auxiliary supply utilizes a transformer winding 5TSB on transformer 5T having a series resistor 120 connected in series with the contacts SS7. The other end of the transformer winding is directly connected to the emitter of transistor T1D. For the purpose of preventing interaction between the alternate base sources for transistor T1D, and "or" gate is employed consisting of diodes 121, 122.

Under initial conditions and prior to pressing the run-inch button, circuits are closed as indicated by the dotted lines in FIG. 6. Thus it will be noted that, with the slide in the top position, and hence with limit switch controls LS2a and LS6a closed, base and collector current are supplied to the transistor T1A. Since the anti-repeat limit switch LS1 is closed, the loop transistor T2 is conducting thereby closing the loop about transistor T1A. Since contacts SS6 of the selector switch perform a bridging function, collector voltage is applied to the power transistors and a second source of collector current is available for transistor T1A from transformer 2T.

When the run-inch button is depressed, transformer 6T is energized supplying collector current to the output transistor stage T1B, T1C. Such current flowing through the primary of transformer 7T turns on the power amplifier energizing the solenoid valve 14. The same circuit which energizes the solenoid supplies collector voltage to the run transistor T1D. Base voltage is supplied to such transistor on a substantially continuous basis through transformer 5T and through contacts SS7 connected thereto so that the run transistor is conductive and continues to energize transformer 7T and the power amplifier even though the run-inch switch is released. That is to say, the press continues to run even though transformer 6T is deenergized and even though the output transistors T1B and T1C are non-conducting.

While it is true that momentary opening of the anti-repeat limit switch LS1 at one point in the cycle (FIG. 2) will momentarily deenergize the transformer 5T thereby removing the auxiliary source of base current to the run resistor T1D, nevertheless it must be kept in mind that the base of transistor T1D is, in addition, supplied with current from the transformer 8T which is energized through contacts SS1 as long as the run limit switches LS2 and LS6 are closed. It will be noted from FIG. 2 that the run limit switches are closed during the time that the anti-repeat limit switch is open. In other words, the run limit switches turn on transformer 8T over a substantial portion of the cycle and in any event for long enough to bridge the gap resulting from the opening of the anti-repeat limit switch LS1. Thus, transistor T1D is assured of a constant supply of base current over 360° of the cycle and, since collector current is also supplied on a continuous basis, the transformer 7T will continue to be energized and the solenoid valve will continue to be turned on indefinitely without further action on the part of the operator.

When it is desired to stop the press the "stop at top" button 23 is depressed thereby opening the circuit to the run limit switch contacts LS2 and LS6. This cuts off one of the two sources of base voltage for the run transistor T1D. However, as long as the limit switch LS1 continues to be closed, base voltage is applied to T1D via contacts SS7 on the selector switch. When the anti-repeat switch LS1 momentarily opens such supply of base voltage is momentarily cut off so that transistor T1D becomes non-conducting, deenergizing the transformer 7T, the

power amplifier and the solenoid valve 14. The latter is accompanied by cessation of collector current in the transistor T1D. When the contacts LS1 close again a moment later base voltage is reapplied to the transistor T1D but since the collector supply has been disconnected, the transistor remains permanently in the off condition. The slide then comes to rest in the top position.

It is of interest to note that during "continuous" operation it is not the opening of the run limit switch contacts LS2, LS6 which deenergizes the clutch but rather the opening of the anti-repeat limit switch, which occurs somewhat earlier (see FIG. 2). This earlier cutoff is, however, highly desirable, since a press under continuous operation will achieve a higher speed than when it is operated on a single cycle basis. Consequently, and in spite of the presence of the usual brake, a press in continuous operation will tend to coast through a somewhat larger angle. The earlier cutoff by the anti-repeat switch tends to compensate for the additional coasting so that the press is brought to a stop in all of its various modes of operation very close to the top position of the slide.

It will be apparent that during the continuous mode of operation the run limit switch overlaps the anti-repeat limit switch to insure that the press is continually energized through successive cycles of operation. Since the run transistor T1D receives its collector current from the power output circuit 80 only momentary interruption of base current flow by LS1, with switch 23 open, suffices to cause the run transistor T1D to "drop out" to stop the press, with the slide at the top.

In addition to the extreme safety, reliable and long life of the control circuit discussed herein, it will be apparent to one skilled in the art that it is inherently compact and inexpensive. Only five transistors are employed in the logic circuitry and two power transistors are employed in the final amplifier. A relatively limited number of diodes is used and these occupy negligible volume. While nine separate transformers are used, these, except for the final output transformer 9T, may be of miniaturized construction. Consequently, the entire control circuit may be fitted on a circuit board having a size which is only a small fraction of the size required in a conventional control circuit using relays.

"Fail safe" operation

It is one of the primary features of the present control circuit that it is "fail safe" as far as operation of the various transistors is concerned. That is, in each of the various transistor circuits output is only produced when there is an input to the base and collector circuits. No output is obtained in the absence of either an input signal to the base or an input signal to the collector. Nor is any output produced in the event of either of the two possible types of failure of a transistor, i.e., open circuiting or short circuiting. Thus the clutch is capable of turning the crank shaft only if all the transistors are working properly and the system is, in effect, self-checking as regards transistor operation.

The "fail safe" nature of the circuit will be apparent upon considering, by way of example, the input and output circuits of the transistor T1A shown in FIG. 7. It will be noted that the input signal to the base is in the form of an A.-C. signal derived from transformer 1T. If desired, and as here shown, the input signal to the base may be in the form of half-wave rectified A.-C., with rectification being provided in the present instance by the diode 34 forming an element of an "or" gate. However, it will be understood that such half-wave rectification takes place in any event at the base emitter junction of the transistor. A source of direct collector current is provided in the output or collector circuit of the transistor T1A in series with output transformer 3T. It is convenient in understanding the operation of the control circuit to consider the transistor T1A as an "and" gate producing an A.-C. output signal whenever separate inputs

are simultaneously applied to the base and collector elements. Preferably, and in accordance with the invention, the second input signal is in the form of an A.-C. wave fed into a transformer winding and with the output of the transformer being full-wave rectified to provide the collector current. In the present instance, the "second" input applied to the collector of the transistor T1A is applied to the primary winding 2TP of the transformer 2T. The secondary winding 2TSA is center tapped as shown, with full wave rectification being provided by the diodes 111, 112 located in the respective legs.

The "fail safe" feature inherent in the circuit may be appreciated by considering two possible types of failure of the transistor T1A. In the first place upon open circuiting of such transistor, no current will flow in the collector circuit even though an input signal is supplied to the base through transformer 1T and to the collector through transformer 2T. The lack of output at the secondary of the transformer 3T under such conditions will prevent conduction in the output transistors T1B, T1C and hence there is no possibility of an input signal being supplied to transformer 7T to actuate the solenoid. Failure of solenoid operation when the run pushbutton is pressed will serve as notification that the circuit should be checked.

With regard to a possible short circuit in the transistor T1A, it should be kept in mind that the normal input to the primary of the signal output transformer 3T is in the form of separate half waves of current passed by the transistor in phase with the half waves of input current at the base. Such separate half waves are effective to produce an A.-C. output signal at the transformer secondary. When a short circuit occurs in the transistor, this produces a heavy flow of direct current through the primary of the transformer 3T in the form of a train of adjacent half waves of current as rectified by the full wave rectifier 111, 112. The transformer 3T is so constructed as to saturate in the face of such heavy flow of D.-C. so that the ripple component is ineffective to induce an appreciable output voltage in the secondary 3TS of the transformer. Thus a short circuit produces zero output. It may be noted that the capacitor 113, in addition to providing a holding action, acts as a filter to reduce ripple content and to insure that no A.-C. signal is passed under short circuit conditions.

It is one of the features of the present circuit that a plurality of inputs are provided in both the base and collector circuits. Thus, while the normal input to the base of transistor T1A may be considered to be the transformer 1T an alternate input is provided, via the loop circuit 53 from transformer 4T. Diodes 34, 52 respectively, isolate these circuits from one another so that each of the two input signals is independently effective to energize the base circuit of the transistor. Moreover, while the collector circuit of the transistor T1A receives its input signal, i.e., energization, from transformer 2T through diodes 111, 112, transformer 10T serves as an alternate source of supply, feeding current through the diode rectifier 37, 38. In addition to serving as full wave rectifiers the diodes 37, 38 and 111, 112 perform the additional function of isolating the two sources from one another.

It is desirable in switching between the alternate sources of input signal to insure maintenance of an output signal so that drop-out does not occur. As stated, this function is performed in the present instance by the capacitor 113. However, the time constant of the capacitor holding circuit should be sufficiently short so that the circuit responds immediately to any actual loss of input in the base or collector circuits so that the clutch-controlling solenoid 15 may drop out as promptly as possible. Securing the desired time constant is a matter within the skill of the art and depends not only upon the size of the capacitor 113 but also the value of the resistor 40 which is in series and the resistor 114 which is in parallel with it.

It is one of the features of the present circuit that it is substantially "fail safe" as far as the diodes in the collector circuit are concerned. Consider, for example, the diodes 37 and 38, which rectify the output of the transformer 10T for energization of the collector circuit of transistor T1A. In the first place such diodes are preferably chosen so that they operate at a small fraction of their actual rating, for example, diodes are used capable of carrying 750 milliamperes but which are actually called upon to carry only 10 milliamperes. Moreover, the diodes are operated at only a fraction of their voltage rating. Consequently there is very little chance for failure, for example, due to voltage breakdown or overheating. When a diode does fail it usually fails by short circuiting. If one of the diodes 37, 38 associated with the transformer 10T should be short circuited, a loop circuit would be formed which includes the secondary winding of the transformer, loading down the transformer and greatly reducing the output voltage. It has been found in an actual test that short circuiting of one of the diodes so reduced the output voltage that the solenoid 15 controlling the air valve would not operate.

With regard to possible open circuiting of the diodes, the effect depends upon which of the two diodes is open circuited. If the diode is open circuited which normally supplies half waves of voltage which are in phase with the current conducted in the input or base circuit, no output will be produced at the secondary of the output transformer 3T even though input signals are present. The lack of output will be evident as a lack of operation of the solenoid, and the press will not operate indicating to the operator that the circuit should be checked. In the event that opposite diode should open circuit, so that there is lack of collector current flow in the inactive portion of the cycle of transistor input current, the circuit will continue to operate. The only effect will be a somewhat reduced effective voltage in the transistor output circuit. This is not especially significant since open circuiting of this transistor cannot produce operation of the air valve in the lack of the requisite input signals and hence does not involve any actual hazard. The only effect is that the circuit may operate with slightly less efficiency. Nevertheless, even this contingency may be guarded against, if desired, by employing several diodes paralleled in each of diode positions. Moreover, the entire circuit may be checked periodically, for example at intervals of several months in order to insure that all of the operating voltages within the circuit are at rated level.

It will be seen from the above that the circuitry associated with transistor T1A is fail safe and establishes a safe condition in the event of failure of any of the components. The fact that all of the components are "static" and free of moving parts constitutes further insurance that the circuit will continue to give troublefree operation for an indefinite period of time. If desired, the various circuits may be "potted" in order to avoid the effects of humidity and to avoid the effects of shock and vibration where the control panel is mounted directly upon the press. This is to be contrasted with the use of relays for control purposes where the presence of dirt between the contacts or where a set of sticking contacts may give rise to a dangerous situation.

While the above discussion has been directed toward transistor T1A and associated circuitry, by way of example, it will be apparent that the same statements hold true for the other transistors in the system. Thus, the transistors T1B and T1C are provided with input transformer 3T supplying the base circuit (of T1B), a second input transformer 6T having diodes 72, and an output transformer 7T. These correspond in all respects to the input and output elements associated with the transistor T1A. Transistor T2 has an input transformer 5T for energizing the base, and input transformer 3T with diodes 45, 46 for energizing the collector, together with output trans-

former 4T. Finally, the run transistor T1D has an input transformer 8T for energizing the base, an input transformer 9T with diodes 105, 106 for supplying current to the collector, and an output transformer 7T. It may be noted that in the present circuit the same output transformer is shared by two fail-safe transistor stages, e.g., transistors T1B and T1C feed the same transformer winding (7TP) as transistor T1D.

In addition to the fail-safe features discussed above, it will be noted by one skilled in the art that additional safety features have been incorporated in the circuit. Thus normally open contacts 22a of the run-inch pushbutton and the normally closed contacts 22b thereof, are not both connected to the same sides of the line; on the contrary, one is associated with power supply line 31 while the other is associated with the line 32. Thus in the event that short circuiting should occur between two sets of contacts in the run-inch switch, the primary of the transformer 6T will be connected effectively in series with the primary of transformer 1T thereby reducing the voltage on the transformer 6T so that the output signal therefrom will be too low to actuate the associated circuits.

In this connection it is a further feature of the circuit that the run limit switches are provided with normally closed contacts LS2a, LS6a, in addition to their normally open contacts, so that they are self-checking. That is to say, the circuit is so arranged that each of the limit switches must open and must close during each cycle of the press and if this does not occur the solenoid 14 will drop out to bring the press to a stop. In considering the operation of the switches it should be noted, first of all, that the normally open and normally closed contacts in each of the switches are positively coupled together so that when one set of contacts is open the other is closed and vice versa. Thus if the switch LS2 is stuck in the closed position the press will not start since the contacts LS2a will be stuck "open." If switch LS2 is, conversely, stuck in the open position, this would not only prevent energization of the transformer 2T dropping out transistor T1A but also it would prevent energization of the transformer 8TP to prevent the run transistor from turning on the solenoid during its portion of a normal operating cycle. Still further fail safe insurance is provided by the fact that both the normally open and normally closed contacts of the switches LS2, LS6 are respectively in series with one another.

With regard to the safety of the power amplifier including the transistors T3A, T3B, it is one of the features of the present circuit that the power supply for these transistors is not secured directly from the A.-C. supply lines but is instead derived from the control circuit itself. Thus it will be noted that the supply lines 91, 92 are energized initially from the transformer 6T which is only energized when the run pushbutton is pressed. At a later point in the cycle the lines are supplied from transformer 2T upon closure of the run limit switches. Even momentary failure of either of the two power supplies during its portion of the operating cycle is effective to de-energize the transformer 9T. Open circuiting of either the transistors T3A, T3B in the power stage is not hazardous and would simply have the effect of reducing the voltage applied to the solenoid but not necessarily below the operating level. Short circuiting of either of the two transistors tends to set up large circulating currents through the secondary windings of the transformer 7T and the primary winding of the transformer 9T to reduce the voltage across the secondary of the transformer to the point where it is not capable of operating the solenoid to turn on the press.

While it has been assumed the above discussion that limit switches are used in the position LS1, LS2 and LS6 having contacts which physically open and close, nevertheless it is contemplated that even these contacts may be eliminated and replaced with fail-safe static circuitry

employing proximity detectors in lieu of the actuating cams. Reference is made to copending application Serial No. 220,458 filed August 30, 1962, for a showing of a suitable proximity switch arrangement.

While the above described circuit is fail-safe against all normal hazards, the circuit may be further safeguarded against an inadvertent permanent short circuiting of the normally closed contacts 22b of the run-inch pushbutton. Such short circuiting is a possibility where the run-inch pushbutton is remotely located at an operating position and where the cable which connects the pushbutton to the control circuit is subject to mechanical hazards. It will be recalled from the above discussion that the "run" transistor stage T1B, T1C performs the function of an "and" gate which serves to energize the clutch when it is turned "on." Such "and" gate has a first or base input which has two sources of supply through the "or" gate comprised of diodes 34, 52. One of the inputs to the base input terminal is the loop circuit including the transistor T2 and "anti-repeat" limit switch LS1. The other base input is supplied from the normally closed contacts 22b of the run-inch pushbutton. Such connection, it will be recalled, requires the pushbutton to be released and reactivated to reestablish the loop circuit after it has been broken by the "anti-repeat" limit switch. Finally, it will be recalled that the normally open contacts of the pushbutton serve to energize the second or collector input terminal of the transistor stage T1B, T1C. In accordance with the present invention, therefore, means are provided, which are operated upon closure of the normally closed contacts 22b for concurrently disabling the first input terminal to the "and" gate. In the present instance such disabling means includes a bridge rectifier 124 connected to the secondary winding 1TS of transformer 1T and the output of which is applied via a resistor 125 to the base-emitter (first) input circuit of the transistor T1B. Thus in the event of a short circuit across contacts 22b, the transformer 1T will continue to be energized and voltage will continue to be applied to the base of transistor T1B having a polarity which biases the transistor T1B for non-conduction. This has the effect of cancelling out the active half-wave input signal from transformer winding 3TSA. With the base input circuit of output transistor T1B thus disabled, such transistor is ineffective to energize the output transformer 7T which, in turn, is prevented from acting, through the final amplifier, to energize the clutch-controlling solenoid 15. This disabling voltage does not affect the normal operation of the circuit since it is turned off when the transformer 1TP is turned off incident to normal pressing of the run-inch pushbutton and since the transistor stage T1B, T1C is not relied upon following closure of the "run" limit switch LS2, LS6.

It may be noted that the above fail-safe condition is not affected by inadvertent short circuiting of the normally open contacts 22a, as may be caused, for example, by a truck riding over the control cable. While it is true that under such circumstances the constant energization of transformer 60 would cause the collector of the transistor stage T1B, T1C to be constantly energized, such stage would not produce an output signal as long as the disabling signal, from the rectifier 124, appeared at the base input terminal. As a result of the above, the run-inch pushbutton may be remotely located with complete safety where convenience of operation requires it.

In the following claims the term "substantially saturate" which is employed to describe the effect of a short circuited transistor upon its associated output transformer is not intended to imply complete saturation but merely the flow of sufficient direct current so that the A.-C. ripple superimposed thereon is ineffective to produce any substantial output signal at the transformer secondary winding.

I claim:

1. In a control circuit for a press having means including a clutch for operating the press, the sub-combination comprising a transistor having an input circuit and an output circuit, means including a first input transformer for applying an A.-C. input signal to the input circuit, an output transformer having its primary winding connected in the output circuit of the transistor and its secondary winding controllingly coupled to the clutch means so that when an A.-C. signal is present in said secondary winding the clutch is energized for operation of the press, a second input transformer having a full wave rectifier for applying an input signal to the output circuit of the transistor, one of said input transformers being connected to a source of conditioning signal and another of said transformers being connected to a source of actuating signal so that the clutch is operated when both the conditioning signal and actuating signal are present, the output transformer having a core of saturable magnetic material so that upon the occurrence of a short circuit in the transistor the resulting current from said input signal to the transistor output circuit is effective to saturate the output transformer so that no A.-C. output signal appears at the secondary winding of the output transformer thereby deenergizing the clutch means of the press notwithstanding the presence of an A.-C. input signal at the input transformers.

2. In a control circuit for press having a clutch means operated by a solenoid control or the like, the sub-combination comprising first and second transistors each having an input circuit and an output circuit, each of said transistors having an input transformer for applying an A.-C. input signal to the input circuit, a second input transformer in the output circuit of each of the transistors and each having a full wave rectifier for supplying unidirectional current, an output transformer having its primary winding connected in the output circuits of the transistors and its secondary winding coupled to the solenoid control so that when an A.-C. signal is present in said secondary winding the clutch is engaged for operation of the press, control means for supplying input signals to the input transformers so that the clutch is operated when signals are present at the input transformers associated with at least one of the transistors.

3. In a control circuit for a press having means including a clutch for operating the press together with a "run" limit switch which is closed during a substantial final portion of the press cycle and an "anti-repeat" limit switch which is normally closed but momentarily opened during the final portion of the press cycle, the combination comprising first and second "and" gates in the form of first and second transistors each having a pair of input circuits and an output circuit, an output transformer having its primary connected to the output circuits of the transistors and its secondary controllingly coupled to the clutch means so that when an A.-C. signal is present in said secondary winding the clutch means is energized for operation of the press, means including a manual pushbutton for applying an input signal to one of the input circuits of the first transistor, means including a holding loop circuit for applying an input signal to the other of the input circuits of said first transistor, means connecting the "run" limit switch to one of the input circuits of the second transistor, means energized coincidentally with the clutch means for applying an input signal to the other of said input circuits of the second transistor so that when the "run" limit switch closes the second transistor is effective to maintain the clutch energized, said "anti-repeat" limit switch being interposed in series with the loop circuit for causing drop out of the first transistor so that the pushbutton must be reactivated to produce a successive cycle of operation of the press.

4. In a control circuit for a press having means including a clutch for operating the press together with a "run" limit switch which is closed during a substantial final por-

tion of the press cycle and an "anti-repeat" limit switch which is normally closed but momentarily opened during the final portion of the press cycle, the combination comprising first and second "and" gates in the form of first and second transistors each having a pair of input circuits and an output circuit, a power amplifier connected to the output circuits of the transistors and feeding the clutch means so that when said amplifier is operative the clutch means is energized for operation of the press, means including a manual pushbutton for applying an input signal to one of the input circuits of the first transistor, means including a holding loop circuit for applying an input signal to the other of the input circuits of said first transistor, means connected the "run" limit switch to one of the input circuits of the second transistor, means for applying an input signal to the other of said input circuits of the second transistor so that when the "run" limit switch closes the second transistor is effective to maintain the clutch means energized, said "anti-repeat" limit switch being interposed in series with the loop circuit for causing drop out of the first transistor so that the pushbutton must be reactuated to produce a successive cycle of operation of the press.

5. In a control circuit for a press having a clutch operated by a solenoid control or the like and a "run" limit switch which is closed during a substantial final portion of the press cycle, the subcombination comprising first and second transistors each having an input circuit and an output circuit, means including a manual pushbutton for applying an A.-C. input signal to the input circuit of the first transistor, means connecting the "run" limit switch to the input circuit of the second transistor, an output transformer having its primary winding connected in the output circuits of the transistors and its secondary winding coupled to the solenoid control so that when an A.-C. signal is present in said secondary winding the clutch is energized for operation of the press, means for supplying the direct current to the output circuits of the transistors, the output transformer having a core of saturable magnetic material so that upon the occurrence of a short circuit in either of the transistors the resulting direct current from the output circuit of the transistor is effective to substantially saturate the output transformer so that substantially no A.-C. output signal appears at the secondary winding of the output transformer thereby deenergizing the solenoid control of the clutch of the press notwithstanding the presence of an A.-C. signal at the inputs of said transistors.

6. In a control circuit for a press having a clutch operated by a solenoid control or the like and a "run" limit switch which is closed during a substantial final portion of the press cycle, the subcombination comprising first and second transistors each having an input circuit and an output circuit, means including a manual pushbutton for applying an A.-C. input signal to the input circuit of the first transistor, means connecting the "run" limit switch to the input circuit of the second transistor, an output transformer having its primary winding connected in the output circuits of the transistors and its secondary winding coupled to the solenoid control so that when an A.-C. signal is present in said secondary winding the clutch is engaged for operation of the press, means including a normally closed emergency stop button for removing power from the solenoid control, and means associated with the solenoid control for applying direct voltage to the output circuit of the second transistor so that when the emergency stop button is momentarily depressed and then released the second transistor is ineffective to activate the solenoid control until such time as the solenoid control is reactivated by the first transistor.

7. In a power press having means including a clutch for driving the slide, the combination comprising a "run" limit switch coupled to the slide and closed from the time that the slide approaches its lowermost position to the time that the slide approaches its uppermost position, an

anti-repeat limit switch coupled to the slide and arranged to be opened momentarily during the time that the run limit switch is closed, a run pushbutton having normally closed and normally open contacts, first transistor means having an input circuit and an output circuit, a first input transformer connected to the input circuit and a second input transformer having a full wave rectifier for applying an input signal to the output circuit, an output transformer in the output circuit controllingly coupled to said clutch means, means connected to the normally closed contacts of the pushbutton for producing an input signal at one of the input transformers, means including a holding loop circuit for effectively maintaining said input signal when the pushbutton is depressed, means coupled to the normally open contacts of the pushbutton for applying an input signal to the remaining one of said input transformers so that an A.-C. signal appears at the output transformer for energizing the clutch and thereby putting the slide in motion, alternate means including the run limit switch for energizing the clutch means to maintain the slide in motion once the run limit switch is closed, and means including the anti-repeat limit switch for breaking the loop circuit so that in the event that the pushbutton is maintained in its depressed condition the clutch means will be deenergized by the opening of the run limit switch to bring the slide to rest in the uppermost position, the output transformer having a core of saturable magnetic material to produce substantially zero output and prevent energization of the clutch means when the resulting current from said input signal to the transistor output circuit flows to the output transformer upon short circuiting of the transistor and in spite of the presence of signals at each of said input transformers.

8. In a power press having a slide and means including a clutch for driving the same, the combination comprising a "run" limit switch coupled to the slide and turned on from a point just prior to the slide reaching its lowermost position to a point just prior to the slide reaching its uppermost position, an anti-repeat limit switch which is normally closed but which is opened momentarily during the time that the run limit switch is closed, a run pushbutton having normally open and normally closed contacts, an "and" gate having first and second input terminals and an output terminal, means including the normally closed pushbutton contacts for establishing an input signal at said first input terminal, means including a feedback loop for maintaining the signal at the first input terminal when the normally closed contacts are interrupted incident to pressing the run pushbutton, means including the normally open pushbutton contacts for establishing a signal at the second input terminal of the "and" gate, the output terminal of the "and" gate being controlling coupled to the clutch means so that the clutch is operated with input signals present at the first and second input terminals of the "and" gate, means for coupling said run limit switch to the clutch means so that the clutch is engaged thereby during the time that the run limit switch is closed, and means for connecting the anti-repeat limit switch in the loop circuit for breaking the loop and thereby removing the input signal from the first input terminal of the "and" gate so that the pushbutton must be released and reactuated in order to institute a successive press cycle.

9. In a control circuit for a press having a clutch operated by a solenoid control or the like together with a "run" limit switch which is closed during a substantial final portion of the press cycle and an "anti-repeat" limit switch which is normally closed but momentarily opened during the final portion of the press cycle, the combination comprising an "or" gate having a pair of input terminals and an output terminal, an "and" gate having a pair of input terminals and an output terminal for energizing the solenoid control when the "and" gate is turned on, the output of the "or" gate being coupled to one of the inputs of the "and" gate, a pushbutton having a set

of normally open contacts for energizing the remaining input terminal of the "and" gate, a set of normally closed contacts associated with said pushbutton for energizing one of the input terminals of the "or" gate so that the "or" gate is normally energized, means including a holding loop circuit around the "or" gate for maintaining the "or" gate turned on when the pushbutton is depressed and in spite of the opening of the normally closed contacts thereof, said holding loop circuit having provision for dropout when the circuit is momentarily broken, means connecting said "anti-repeat" limit switch in said loop circuit and means associated with said press for opening said "anti-repeat" limit switch so that the loop circuit is broken during each cycle of the press and so that the pushbutton must be released and reactivated to energize the solenoid control for a subsequent cycle of operation.

10. In a control circuit for a press having means including a clutch for operating the press, the combination comprising a plurality of transistor logic stages connected together so that the output of the final stage is associated with the clutch and the clutch is energized in response to the production of an output signal at said output, each of said logic stages including a transistor, a first input transformer connected to the input circuit of the transistor and a second input transformer connected in the output circuit of the transistor, each of said output transformers having a core constructed of saturable magnetic material so as to substantially saturate when the rectified A.-C. current flows in the output transformer primary winding upon short circuiting occurring in the transistor output circuit thereby insuring deenergization of the clutch means upon failure of any one of the transistors.

11. In a control circuit for a press having means including a clutch for operating the press together with a "run" limit switch which is closed during a substantial final portion of the press cycle and an "anti-repeat" limit switch which is normally closed but momentarily opened during the final portion of the press cycle, the combination comprising an "or" gate having a pair of input ter-

minals and an output terminal, an "and" gate having first and second input terminals and an output terminal for energizing the clutch means when the "and" gate is turned on, the output of the "or" gate being coupled to the first input terminal of the "and" gate, a pushbutton having a set of normally open contacts for energizing the second input terminal of the "and" gate and a set of normally closed contacts for energizing one of the input terminals of the "or" gate so that the "or" gate is normally energized, means including a holding loop circuit connected from the output of the "or" gate to the remaining input terminal thereof for maintaining the "or" gate turned on when the pushbutton is depressed and in spite of the opening of the normally closed contacts on the latter, said holding loop circuit having provision for drop out when the circuit is momentarily broken, said "anti-repeat" limit switch being connected in said loop circuit so that the loop circuit is broken during each cycle of the press so that the pushbutton must be released and reactivated to energize the clutch means for a subsequent cycle of operation, and means operated by the closure of the normally closed contacts on the pushbutton for concurrently disabling the first input terminal of the "and" gate so that upon accidental permanent short circuiting of said normally closed contacts the "and" gate is ineffective to operate said clutch means to put the press in motion.

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