

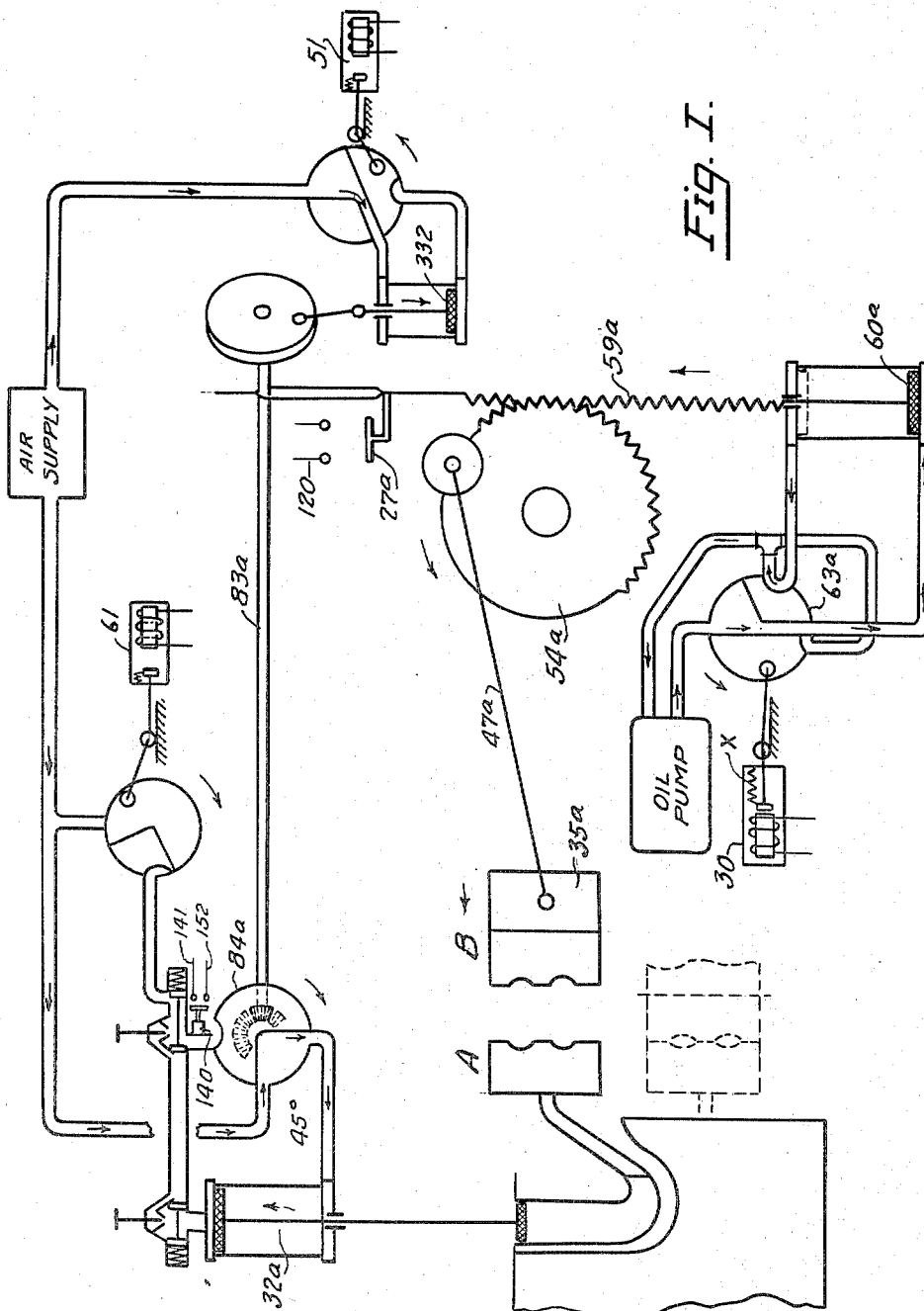
Nov. 28, 1950

B. F. HOLMES ET AL
METHOD OF DIE CASTING

2,532,256

Filed Dec. 10, 1947

7 Sheets-Sheet 1



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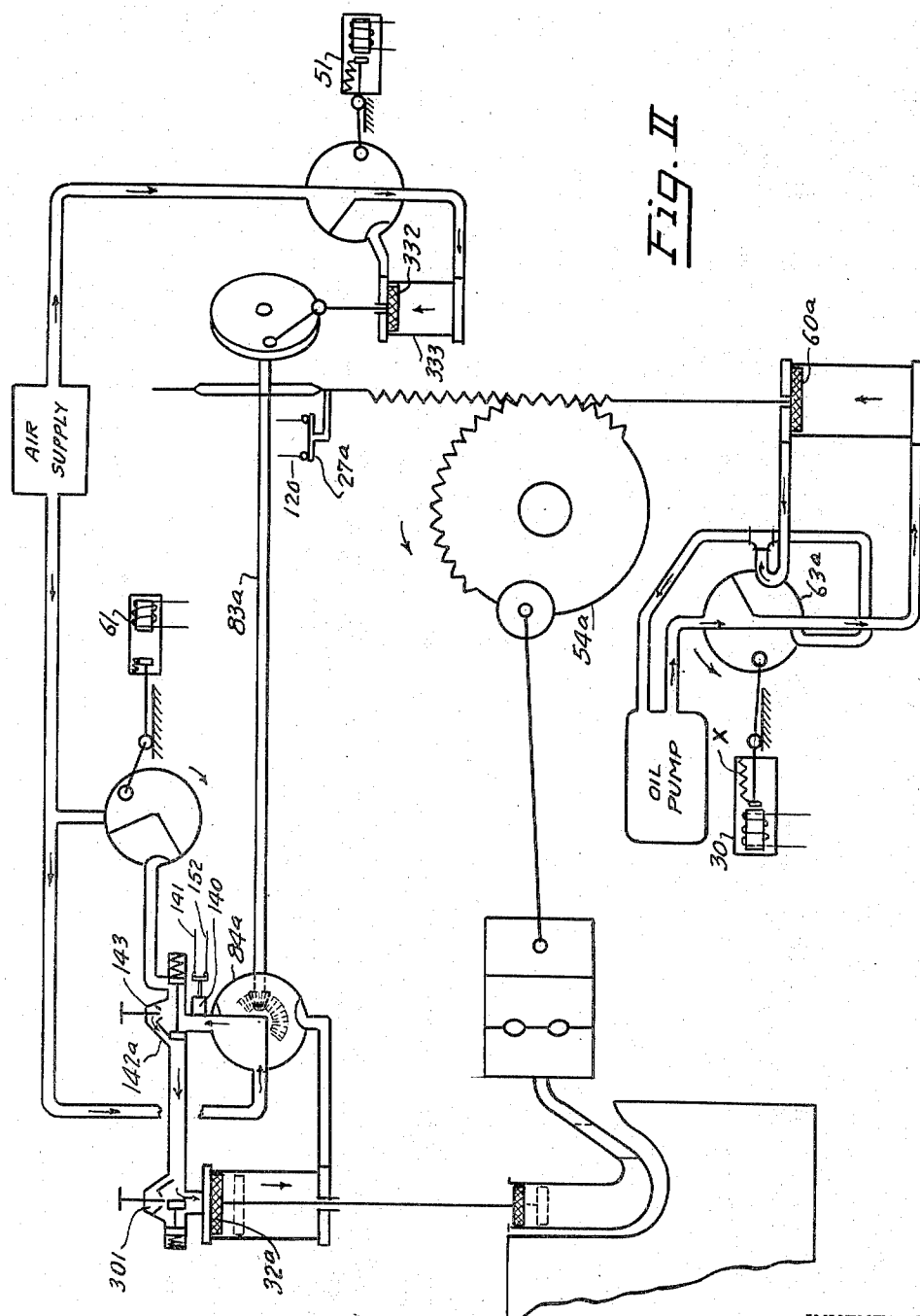
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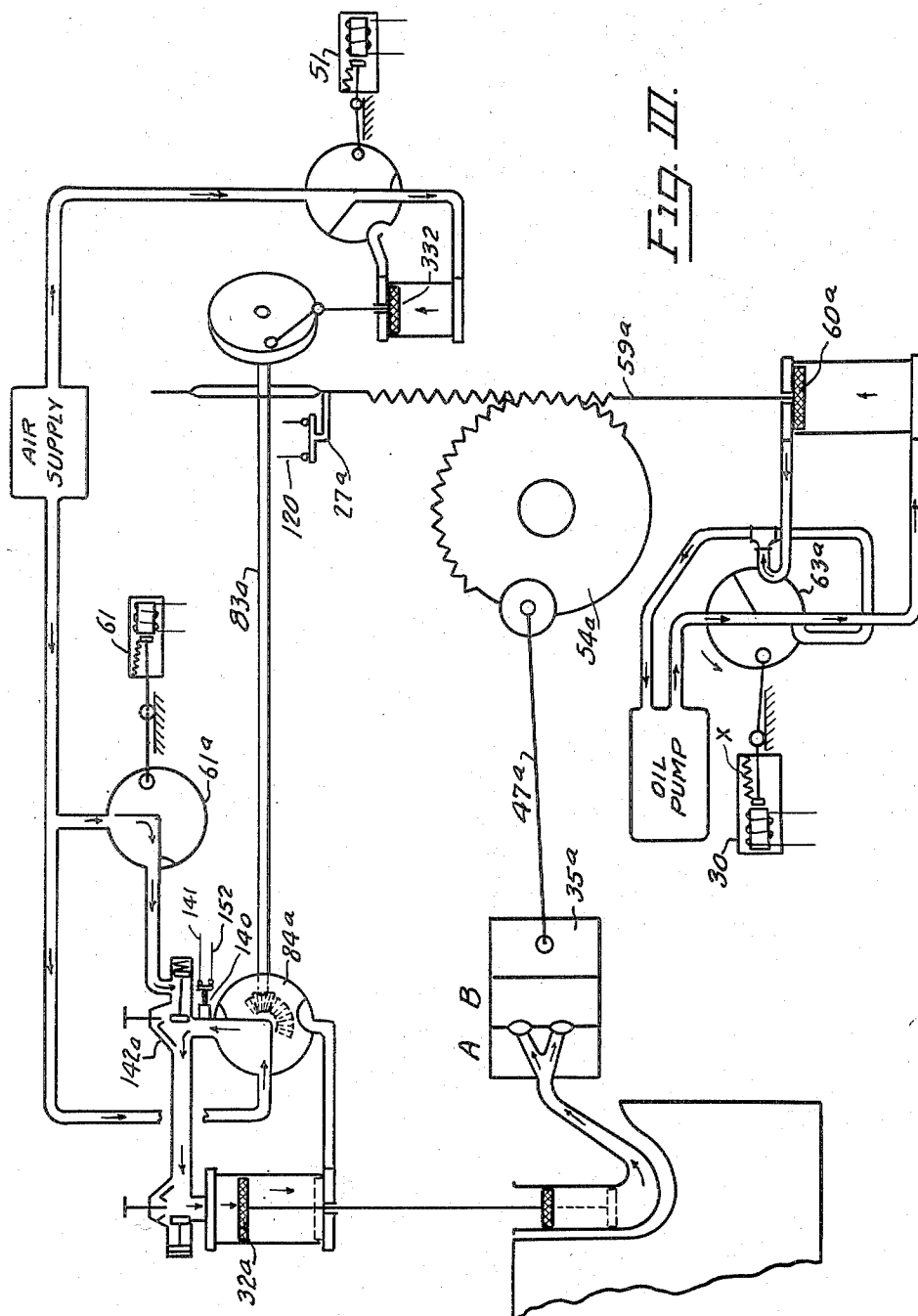
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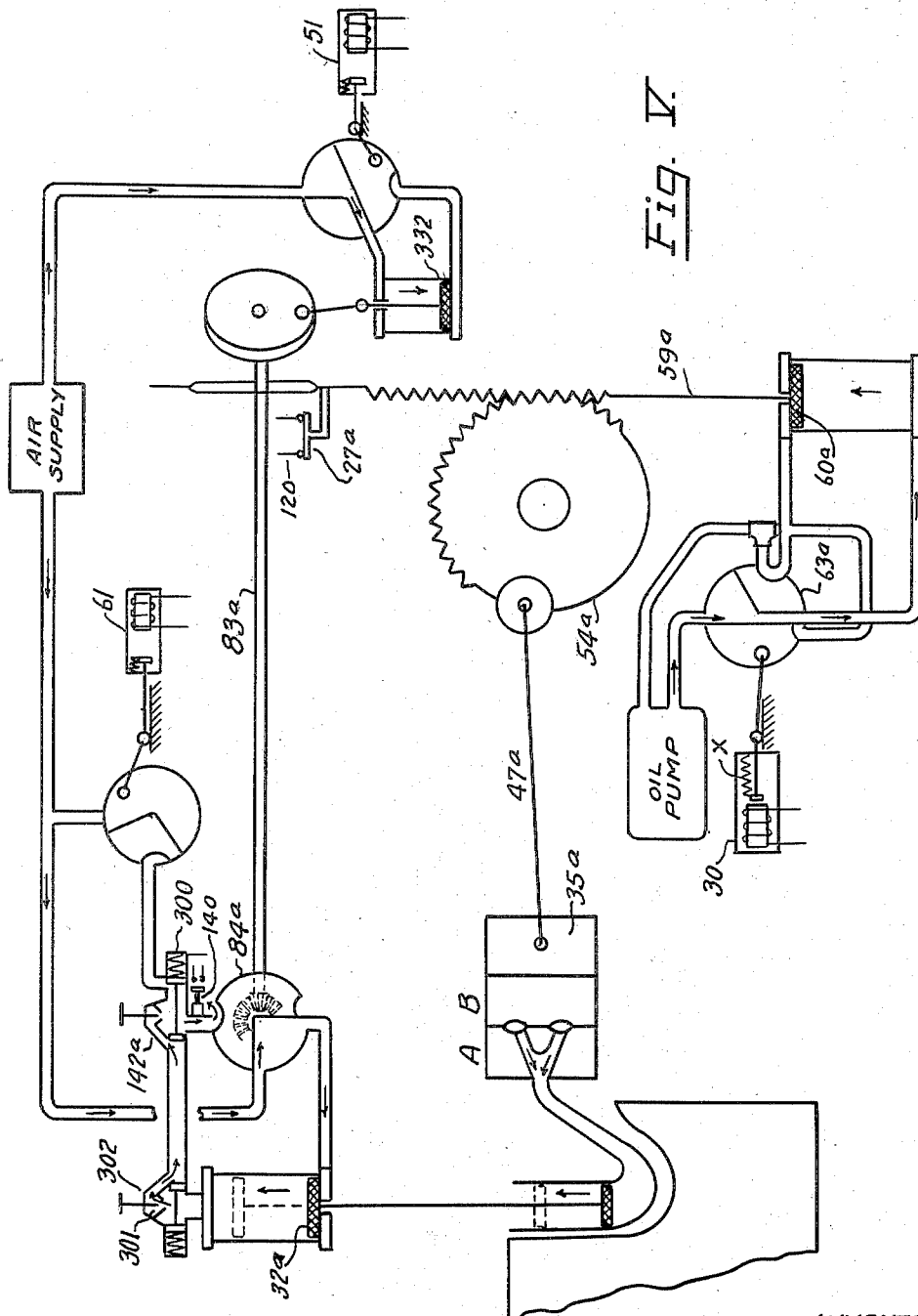
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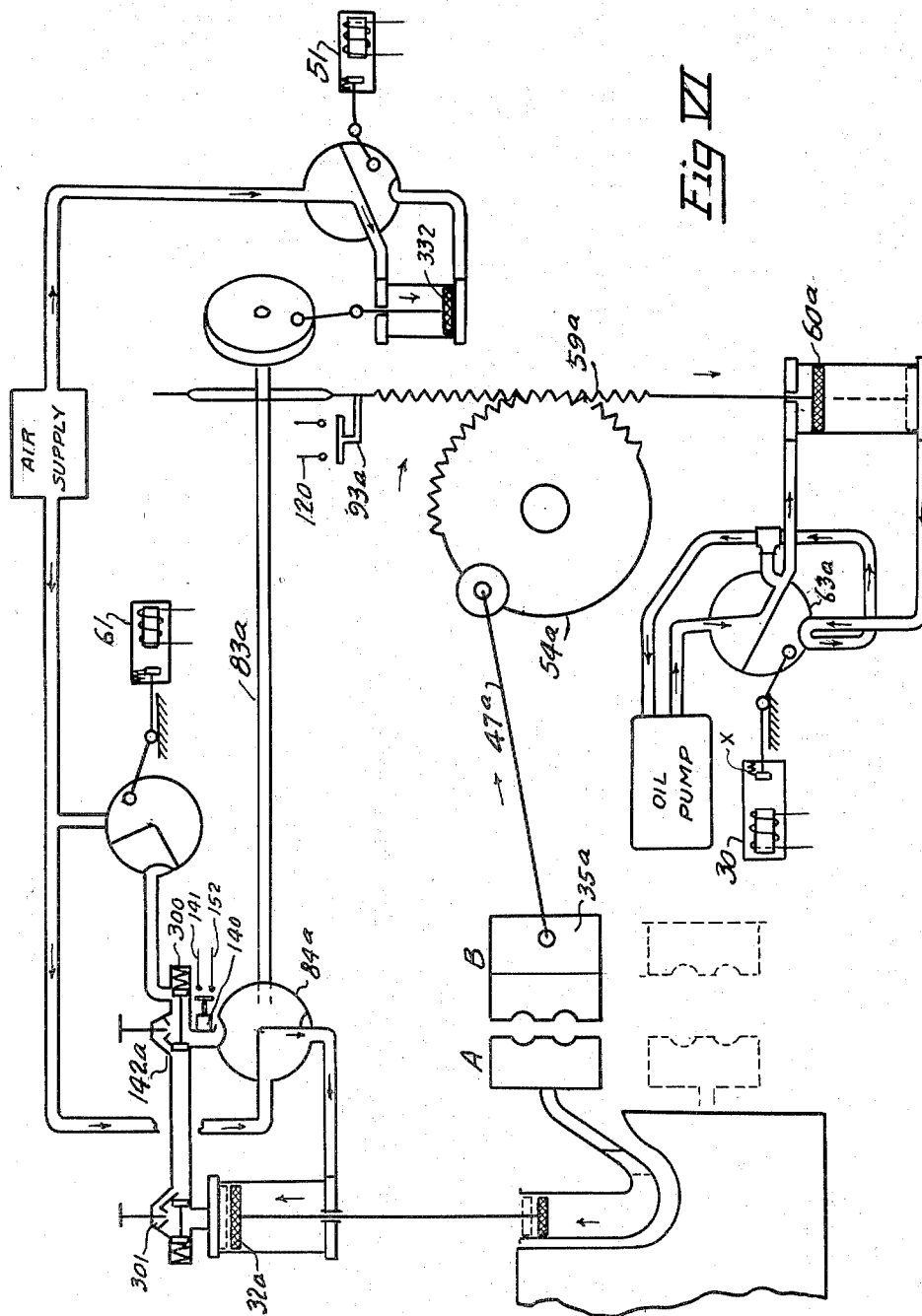


Fig. VI

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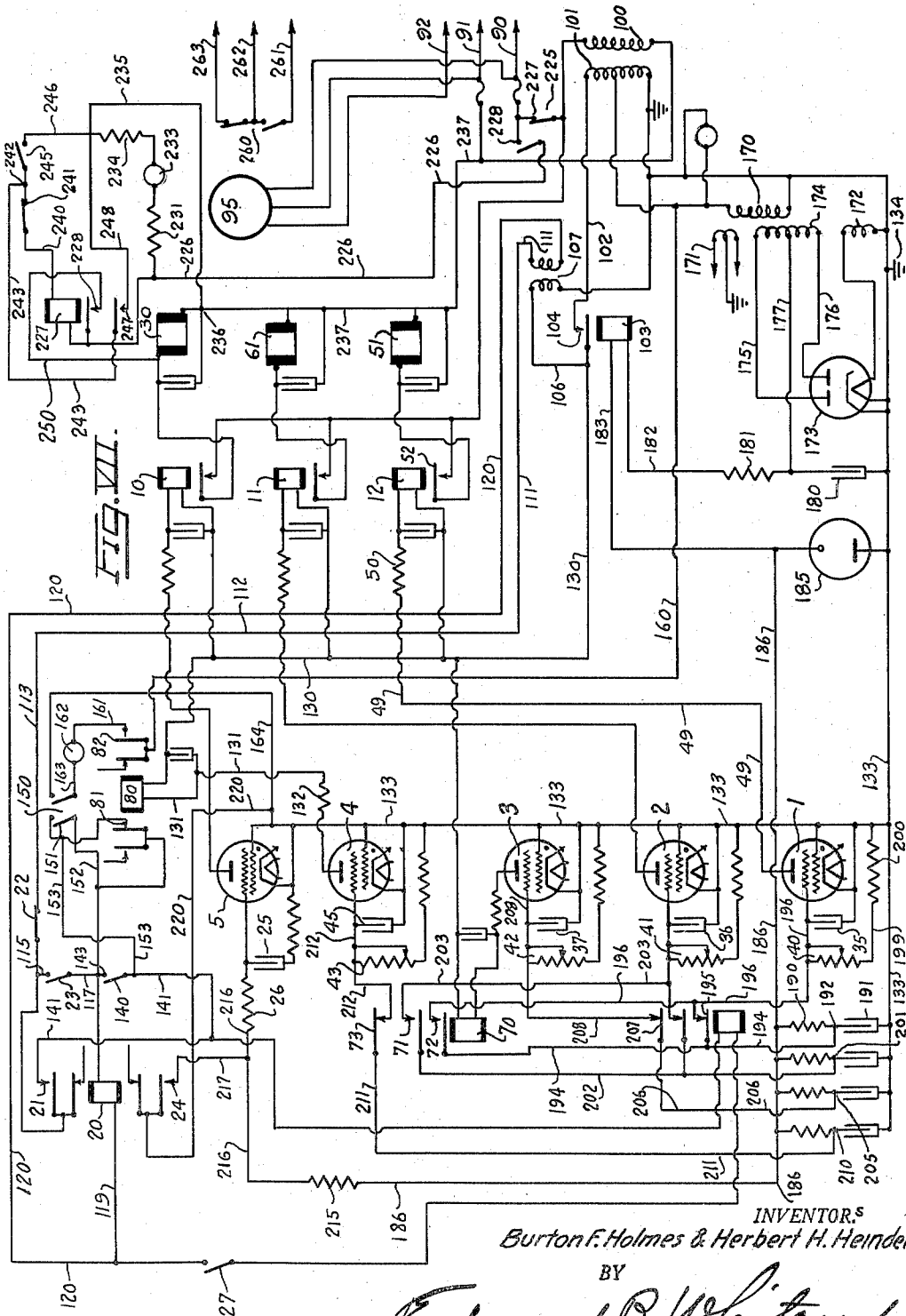
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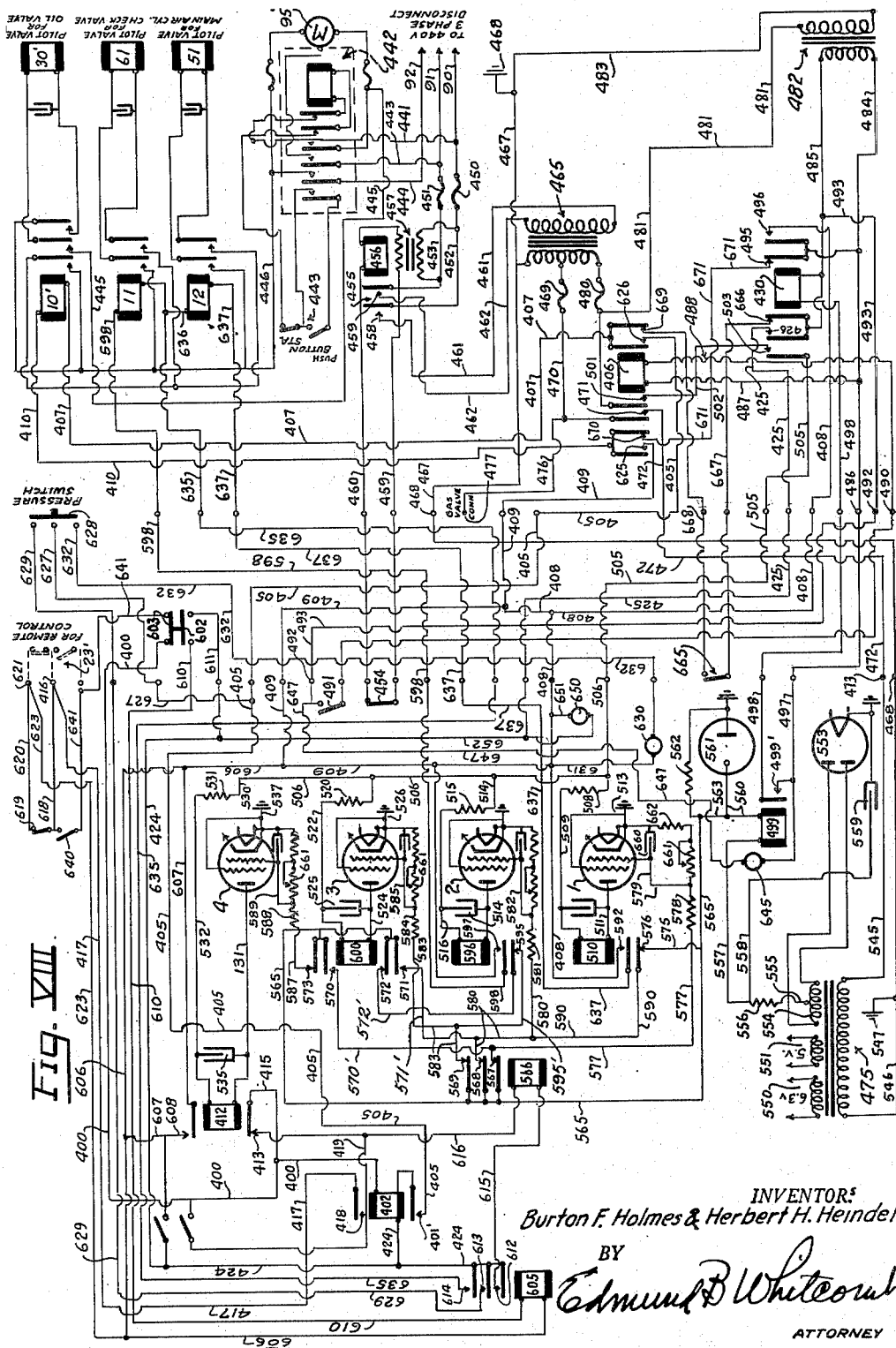
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UNITED STATES PATENT OFFICE

2,532,256

METHOD OF DIE CASTING

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2 Claims. (Cl. 22—209)

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This invention relates to an electrically operated, automatic control for die casting machines, including an extremely accurately controllable, electro-mechanical means for increasing the productivity of a die casting machine. The new method involves the efficiency of the die casting operations and particularly a more accurate control of the injection of the metal, in two stages including its retention in the die under pressure for correct solidification and correct and improved method of cutting off the supply.

Further objects and advantages are within the scope of this invention, such as relate to the details of the operation of the method as will be understood from a consideration of the specification and drawings of certain forms of the invention, one of which may be preferred, in which:

Figure I is a diagrammatic view of one type of die casting machine to which our invention has been applied—Figure I representing the operation of closing the dies.

Figure II is a diagrammatic view similar to Figure I, in which a preliminary or delayed injection of the casting metal operation is taking place.

Figure III is a similar diagrammatic illustration of the machine during the main injection operation;

A separate Figure IV is not included although an important separate step is hereinafter described. The mechanism in step IV is the same as that illustrated in Figure III;

Figure V is a similar diagrammatic illustration showing the cooling time of the machine with the air control piston returning to normal position;

Figure VI is a diagrammatic illustration of a mechanism illustrating the opening of the dies;

Figure VII is an electrical diagram of a control embodying our invention as applied to the type of mechanism illustrated in Figures I through VI;

Figure VIII is a view similar to Figure VII of a modification of the circuits and respective controls thereof.

In certain embodiments of our invention, we have shown a certain electrical control system, which we have invented as applied to the operation of the die casting machine, such as that illustrated in the prior patents to Schultz et al. for "Method for Casting Metals," Patent No. 2,108,080, dated February 15, 1938, and to Schultz et al. for "Apparatus for Casting Metals," Patent No. 2,173,377, dated September 19, 1939.

Fundamentally, our invention relates to an electronic control system or method for controlling the valves of the mechanism which operates

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a die casting machine, and the operation involves the following main steps:

1. Machine closing—die closing, illustrated in Figure I.

2. Casting metal injection started (slow)—illustrated in Figure II.

3. Heavy shot of casting metal (fast)—illustrated in Figure III.

4. Pressure held on the metal in closed die—no Figure IV—illustrated in Figure III.

5. Return of the metal injecting piston to normal position—illustrated in Figure V.

6. Machine opening—die opened—illustrated in Figure VI.

Referring more specifically to the various diagrammatic figures of the drawings illustrating various positions of the machine, in the position of Figure I, the action of the machine and the operation of our electrical control involves the following sub-steps:

A. Operator presses close button 23, wiring diagram Figure VII (23', Figure VIII).

B. Tube 5 fires—relay 10 and coil 30 of oil pilot valve is energized in Figure VII. In Figure VIII, relays 402 and 406 energize coils 10' and valve 30'.

C. Main oil valve 53a on die casting machine is thereupon operated so that oil piston 50a moves rack 59a, rotating gear 54a, pitman rod 47a, moving die plate 35a in direction of arrow to close the dies A and B.

D. Machine thus closes.

E. Machine locks up and closes microswitch 27 (Figure VII). In Figure VIII, the machine moves switch 602 to closed position. In both cases this effects time delay firing of tube 1 controlled in Figure VII by potentiometer 40 and in Figure VIII by potentiometer 661.

In Figure II, the following steps are involved:

A. Tube 1 fires.

B. Air pilot valve coil 51 is energized through relay 12'. A source of air pressure supply is obtained from a suitable compressor system for all air valve and air piston operations.

C. This causes operation of supplementary air cylinder and piston 332 acting to turn the shot lever 33a causing operation of main air valve 84a, which exhausts air from below main air operated piston 32a.

Rotating shot lever 83a also connects the air supply through valve 84a to the air regulating or check valve mechanism 142a permitting air to be supplied by a small bleed connection 143a to the top of piston 32a.

D. This starts main air cylinder piston 32a

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slowly downwardly at reduced pressure in delayed shot action.

E. Tube 2 has not yet fired but is on its delay period set by potentiometer 41, as shown in Figure VII, or potentiometer 661 as shown in Figure VIII.

In Figure III the following steps are involved:

A. Tube 2 fires.

B. Air pilot valve coil 61 is now energized through relay 12.

C. Regulating or check valve mechanism 142a is opened wide by air pressure supplied from air pilot valve 61a for coil 61.

D. Main air cylinder now receives full air pressure behind piston 32a and main metal injection takes place with a heavy shot, the full pressure on the metal being in excess of one thousand pounds per square inch as indicated in the prior Schultz patents above referred to, in contradistinction to prior art types of machines in which the metal is open to atmospheric pressures.

E. Tube 3 has not yet fired but is on its time delay which is controlled by its potentiometer 42 as shown in Figure VII or potentiometer 661 as shown in Figure VIII.

Step IV, illustrated in Figure III, involves the following sub steps:

The mechanism is in the same position as in Figure III including the position and operation of the valves, as indicated at the end of cycle of Figure III, hence, no special diagram is illustrated of this Step IV. Step No. IV is mainly for permitting the metal in the die to become "set."

A. Set time operation which begins with the end of shot operation and is the time between the firing of tube 2 and the start of main air cylinder piston's return caused by the firing of tube 3 (which has not yet fired), in the embodiment illustrated in Figure VII.

In the embodiment of Figure VIII, the start of the main air cylinder piston's return is caused by the firing of tube 3.

B. Pressure is held on the metal during the time delay for the firing of tube 3 which is determined by the setting of its potentiometer 42, as shown in Figure VII or potentiometer 661 as shown in Figure VIII.

In Figure V the following sub steps are involved:

A. Tube 3 fires rebiasing tubes 1 and 2 and starting the time delay for tube 4.

B. Air pilot valve coils 51 and 61 return to their de-energized positions.

C. Air is applied to top of piston 332 for operating lever 83a to return main air cylinder valve 84a to its initial position to supply air to the bottom of piston 32a.

D. Air is cut off from pilot line of air controlled valve mechanisms actuated by air pilot valve coils 61, which is now de-energized, allowing spring 300 to reset it.

E. Main air cylinder piston 32a begins its return stroke regulated by the bleeder 301 valve setting on return check valve 302.

F. Cool time is the delay setting of the potentiometer 43 for tube 4, as shown in Figure VII or potentiometer 661 as shown in Figure VIII.

Figure VI involves the following sub steps:

A. Tube 4 fires.

B. Machine control holding circuit opens—circuit including relay 29 is opened by relay 39, illustrated in Figure VII, while in the embodiment illustrated in Figure VIII, relay 402 is opened by relay 412.

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C. As shown in Figure VII, tube 5 is rebiasing, deenergizing oil pilot valve coil 30 which causes machine to open. Since oil valve 63a is now returned to the position shown in Figure VI, and oil is supplied to the top side of the piston 60a, moving rack 59a, downwardly, turning gear 54a in the direction of the arrow so that pitman arm 47a now opens the dies A and B, as shown in Figure VI. As illustrated in Figure VIII, tube 5 is omitted entirely and the firing of tube 4 acts through relays 412, 402 and 406 to de-energize oil pilot valve coil 30 which permits dies to open as described for Figure VII.

D. Machine opening causes microswitch 27, illustrated in Figure VII, and 602 (Figure VIII) on safety bar 93a to open.

E. As shown in Figure VII, this energizes relay 33 causing bias to be reapplied to tubes 1, 2, and 3, stopping flow of plate current in tube 3 which de-energizes relay 70. As shown in Figure VIII, opening of microswitch 602 provides bias to all tubes, the tubes 1 and 2 having been previously rebiasing by the firing of tube 3.

F. In both embodiments (Figures VII and VIII) the rebiasing of tube 4 resets the circuits for the next cycle of machine operation.

The main control of the die casting operation is by one hydraulic mechanism (for die operation) and two air controlled valves operated through the network disclosed including the main relays 10, 11 and 12 so that the proper operations of these relays controls the machine operation step by step as indicated.

It is important that the safety button 22 is normally closed, and when it is closed the 24-volt current is supplied to the main manual quick return control button 23—23' in Figure VIII. This main control button 23 is a momentarily operated type, which, when pressed by the operator, supplies current to the relay 20, energizing the relay, thereby closing points 21 which are thereupon held closed continuing thereafter to maintain the machine in automatic control for one complete cycle. The machine then automatically stops so that the operator may remove the casting. All parts of the machine are then in proper position for recycling the operation and the operator may continue producing castings at will.

Embodiment illustrated in Figure VII

The first operation—closing the dies (Figure I) is effected by firing of the thyatron of space discharge tube 5. The tube 5 is, until firing, under a normal bias of 75 volts. When the relay 20 is energized, it also operates point 24 which short circuits the bias circuit to the grid of tube 5 through the condenser 25 and resistance 26. This action of removing the bias from tube 5 causes the same to fire (through the time delay mentioned), and this operates relay 10, its corresponding contacts and supplies 440 volts to the main oil pilot valve 30 for closing the die casting machine.

When machine closes, microswitch 27A, which is normally open, also closes thereby applying 24 volts to relay coil 33. Relay 33 has three relay points normally closed which apply bias to tubes 1, 2, and 3. When coil 33 is energized, these three points of relay 33 open, and the bias is removed serially from each tube 1, 2, and 3, and each condenser 35, 36, and 37 for each such tubes 1, 2, and 3 will discharge through their corresponding potentiometers 40, 41, and 42, according to the setting of the potentiometers.

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This triple contact relay 33, while operating the points, simultaneously has the effect of causing the tubes 1, 2, and 3 to fire in series, due to the various settings of their respective potentiometers 40, 41, and 42.

Specifically, tube 1 fires when its grid voltage reaches the critical point. Current then flows from tube 1 through lead 49, resistor 50, to relay coil 12 energizing the same and closing its normally open contactor or switch 52, thereby applying 440 volts to shot air valve 51. When air valve 51 operates in the die casting machine, it operates a two-way air cylinder, which turns the shot lever, turning the main four-way air valve. This is the first part of the injecting the metal (which is done through a check valve controlled by tube 2, hereinafter described), and the air is completely removed from the lower side of the main air cylinder.

Tube 2 operates in a similar manner to supply current to relay 11, first operating its switch and then the air valve coil 61. This air valve 61 controls the supply of air to the controlling means for the check valve, above referred to, and removes its checking effect on the main operation of the casting machine, and now the main step of injecting the metal quickly is accomplished by the machine.

In view of the fact that both tubes 1 and 2 have now fired, a pressure is held on the metal in the die for a certain length of time, which is very important in this die casting machine. This pressure of the dies closed is held until tube 3 fires, which removes this as will now be described.

Thyratron tube 3 is interconnected in the system through relay 70 so that when tube 3 fires, it again changes the control grids of tubes 1 and 2 back to bias position. Tube 3 has its time delay (through condenser 37, potentiometer 42, hereinafter described), and this action holds the pressure on the dies, as just stated. Firing of tube 3 has the effect of releasing both coils 51 and 61 and their corresponding air valves, and the machine parts are mechanically returned to normal. Thus, upon firing of tube 3 (when relay 33 has acted as stated above) current flows through the coil of relay contactor 70 and closes the two normally open switches 71 and 72 and opens the one normally closed switch 73. The two closed switches now operate to reapply bias to tubes 1 and 2 which breaks the plate circuit and de-energizes relays 11 and 12 and thus removes the 440 volts from the two air valves 51 and 61. Actually, in the die casting machine at this point, the air valve 51 has the double function of now causing the lever to be turned back to normal position, which allows the main air valve to turn back to normal position allowing the piston to return to normal, since air is admitted to the other side. In the meantime, releasing air valve 61 has released the check valve previously referred to as controlled by tube 2.

Current input circuit

The main input circuit leads 90, 91, and 92 of the three phase, 440 volt, input circuit are shown on the drawing, the lead 92 being connected to the operating motor 95, as will hereinafter be described and set forth. The leads 90 and 91 are the two main leads for supplying the current to the electrical control system for the die casting machine.

This supplies A. C. energy to the transformer 100, which reduces the voltage on two secondaries to 110 and 220, respectively. The lead 102 for the

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220 volt circuit extends from the secondary 101 to the point of time delay relay 103, the point being designated by the numeral 104. This point is normally open. Upon energizing relay 103, this point closes and connects lead 102 through lead 106 for the 24-volt control circuit transformer 107. This transformer 107 has a lead 111 which is connected by lead 112 and lead 113 through safety open switch 22 to the point 21 of the relay 20 described above. When the automatic switch 23 is closed, this energizes the relay 20, as indicated supra. For the purpose of energizing coil 20, a lead 115 is connected with lead 113 and through automatic closed button 23, lead 117, through lead 118, to the relay 20 as shown. The return circuit starts from relay 20 through lead 119 and is connected to lead 120, which returns to the other side of the transformer 107. This circuit, however, is merely a momentary circuit, and it requires the operation of a hold circuit to actually control the relay 20 which will be hereinafter described.

For controlling relay 10, the control voltage is applied to the 24 volt coil 20. When the button 23 is pushed, voltage is applied across the relay 20, energizing the relay and causing the bias to be shorted out on tube 5, as indicated above, which causes the tube to fire after a short time delay due to the condenser 25 and resistor 26. This operates the relay 10 and its switch, which supplies 440 volts to the main oil pilot valve coil 30 causing the machine to close.

The microswitch 27 is normally open, but is closed when the machine "locks up"—which is done mechanically as in the prior patents above referred to—and closing microswitch 27 thereby applies voltage 24 volts to relay 33.

Transformer 170 supplies 6.3 volts from secondary 171 to the filaments of each thyratron tube 1, 2, 3, 4, and 5 (circuit not shown).

Another secondary 172 of transformer 170 supplies 5 volts to the filament of rectifier tube 173. Another secondary 174 supplies voltages to plates of rectifier tube 173 through leads 175 and 176, as shown. A center tap 177 is connected to a filter condenser 180, the other side of said filter being connected to ground lead 133. This center tap 77 is also connected to resistor 181 connecting lead 182 to relay coil 103. The other side of coil 103 is connected by lead 183 to regulator tube 185 cathode, the anode being connected to ground lead 133.

Bias supply for tubes 1, 2, 3, 4, and 5

Tube 185 maintains 75 volts across it despite variations in supply voltage. Lead 183 also connects to lead 186, which is the main bias supply lead for all the thyratron tubes 1, 2, 3, 4, and 5. Specifically, this is arranged by providing a set of filters for each tube, excepting tube 5.

For tube 1, we have shown connected from lead 186 a filter, consisting of a resistor 190, condenser 191, connected to ground lead 133 and between the two at point 192, there is a lead 194. This lead 194 is connected with point 195 on relay 33 and point 72 of relay 70. The other side of point 195 is connected by lead 196 to the control grid of tube 1. Lead 196 is also connected to the normally open point 72 of relay 70. This control grid is the "trigger" action for tube 1.

The filaments of each of tubes 1 to 5 is supplied with 6.3 volts circuit from the secondary 171 of the "bias" transformer 170.

In operation of tube 1, the point 195 of relay 33 being normally closed, the bias supply through

lead 186, resistor 199, from point 192, lead 194, point 195, lead 196, charges the condenser 35. When the bias is removed, as will hereinafter be further referred to, the point 195 opens by reason of the action of relay 33, and consequently, the condenser 35 will then discharge through the potentiometer 40 and a controlling resistance 200 to the ground lead 133. This resistance 200 is to limit the flow of current when the potentiometer is set at zero, which would otherwise draw too much current from the bias supply at 192 and might ruin the potentiometer 40.

The bias for tube 2 is identically arranged as described in connection with tube 1, the corresponding resistor and condenser having the connection 291 for lead 262, which is connected to point 71 of relay 70, point 71 having lead 263 for connection to the control grid of tube 2, the timing circuit for tube 2 being by way of condenser 36 and potentiometer 41. We also provide a limiting resistance, such as 290 for tube 2.

The bias for tube 3 is from connection 285, through lead 286, to normally closed point 207 of relay 33, lead 293, to the control grid of tube 3. Tube 3 also has a timing circuit similar to that described, supra, as to tubes 1 and 2, by way of condenser 37 and potentiometer 42.

The bias for tube 4 is from connector 210, lead 211 to normally closed point 73 of relay 70, lead 212 to the control grid of tube 4 which also has a timing circuit similar to that of tubes 1, 2, and 3, but by way of condenser 45 and potentiometer 43. The firing of tube 4 will be hereafter set forth.

The bias for tube 5 is from the main bias lead 186 through current limiting resistor 215, lead 216, lead 217 to normally open point 24 of relay 20, lead 216 also being connected through time delay resistor 26 to the control grid of tube 5.

The firing of tube 5 and removal of the bias occurs when normally open point 24 closes by reason of the action of relay 20. When point 24 closes, the lead 217 becomes a ground connection, since point 24 is now connected through lead 220 to ground lead 133.

When relay 20 operates to close point 24, then the condenser 25 for tube 5, which is holding the voltage on the grid of tube 5 due to the charge of condenser 25, discharges through resistance 26, lead 216, 217, point 24, lead 220, to ground 133.

The operation of firing of tube 4 which has the effect of "opening" the casting machine will now be described.

To do this, since tube 3 has fired, the bias supply has been removed from tube 4 (after the time delay, through potentiometer 43 and condenser 45 has taken place). This energizes relay coil 80 through connector 130, which has 220 volts A. C. being connected to point 104 of relay 103. The other side of relay 80 has lead 131, resistor 132 to the plate of tube 4. The cathode, which is the return circuit of tube 4, is connected by lead 133 to ground 134.

Relay 80, having now been energized, it opens normally closed point 81 which is in the holding circuit for relay 20 coil. This removes current from relay 20, allowing it to deenergize and open point 21 and point 24, which restores bias to tube 5 and hence deenergizes oil pilot valve 30 which operates fluid to main oil valve and mechanical means such as spring X effects an opening of the dies, as will be understood.

As a safety device, we also have a control, so that if any air is on the main air cylinder (which

injects the metal) the dies cannot open. To do this, we have an air pressure operated switch 140 connected from point 21 by lead 141 to one side of 140. The other side of switch 140 is connected by lead 152 to lead 118 to relay 20. This puts switch 140 across relay point 81 and prevents the holding circuit from being opened or broken as long as there is air pressure in the upper side of the main air cylinder.

We also have a further control so that with certain dies necessitating the core's being removed before the die is opened, the machine will not open but shows a light so that the operator may time his operation and actually remove the core before the machine is opened. To do this, we use a double pole manual switch 150 which maintains, when closed, voltage on relay 20 even though relay 80 would have otherwise opened 20 as when tube 4 fires. To this end, we provide a set of points 151 for switch 150. Lead 118 connects to 151 through lead 152, and the other side of switch 150 is connected by lead 153 to lead 141 to point 21 of relay 20 (hence to supply circuit).

The pilot light circuit (controlled by switch 150) is as follows: 110 volts from supply circuit lead 160 is connected to point 82 of relay 80, lead 161 to pilot light 162, lead 163 to switch 150. The other side or point 155 of switch 150 connects with lead 164 to ground lead 133.

We also provide a manual circuit whereby the machine may be manually operated in conjunction with the foregoing, and in this connection we provide a manual automatic switch 225 connected with input lead 90 having a lead 226. In the drawing, the switch 225 is shown in the automatic connection with the point 227 closed to transformer 100. When it is desired to use the machine manually, the switch is closed to the point 228 which is normally open and also the pilot light circuit. The lead also connects through lead 230, resistance 231, to the pilot light 233, resistance 234, return lead 235, connection 236, lead 237 to the other input supply lead 91.

The coil 227 has a lead 240 connected with normally closed push button switch 241, lead 242 and switch 245. The other side of the switch 245, which is open, is connected by lead 246 to the return lead 235. By closing switch 245 manually, the coil 227 is energized because a closed circuit has been established to the input and output main lines 90 and 91. When this is accomplished, point 228 closes and applies 440 volts across the oil pilot valve 30 for the main casting machine connection. When the relay 227 is energized, it also closes the point 247 and establishes a holding circuit for coil 227, by reason of connection 242 to lead 243, to point 247 which is now closed, and lead 248 connects the same to return lead 235 which brings it to lead 91.

When point 228 of the relay 227 closes, a lead 250 connects the same with coil 30 of the oil pilot valve, it being understood that the main input circuit from lead 90 connects through lead 226 to the point 228 as well as the coil 227.

We also provide circuit arrangements for connecting the power line to the motor of the machine, which builds up the oil pressure for operating the machine. Moreover, these circuits control the connections for the main input supply lines 90 and 91. To this end, we provide a push station 260 interconnected with the three leads 261, 262, and 263. These three leads are push station leads from a magnetic starter (not shown) which connects the main outside power lines to the leads 90, 91 and 92.

Embodiment illustrated in Figure VIII

We show in Figure VIII, a further embodiment of our invention. Here, the diagrammatic connection from the power line to the machine is indicated at 23' which includes the automatic return push button 640, which, being connected to the power closes the circuit through the micro-switch 603 and lead 400 to coil 402 to close its contacts so that the casting machine dies close, as in Figure I, relay 402 being the key relay for controlling the die operations in the embodiment of Figure VIII. Lead 405 extends from switch 401, lead 405 to relay 406 having normally open switch point 626 on the power panel and connected with the input circuit as will be hereinafter pointed out. Then, a lead 407 extending from the other side of relay switch point 626 connects with relay 10' causing an operation of the pilot valve and hence the die actuating mechanism. The other side of this circuit from coil 10 is by lead 410, point 625 of relay 406, hence, by lead 409 to main power switch relay 430. (the input circuits to be described).

This 24 volt circuit closed by relay 10' energizes coil 30' to close the die operating mechanism, the circuit for coil 30' being a 440 volt circuit from the power line.

Tubes fire in sequence, effecting casting machine operation

Following the operation of said die closing circuit controlled by relay 402 in Figure VIII, the thyratron tubes 1, 2, 3, and 4 fire as in Figure VII. Tubes 1 and 2 control the metal injection in two stages. Tubes 3 and 4 reset tubes 1 and 2. Thus, tube 1 fires causing slow injection of molding metal as shown in Figure II; then tube 2 fires—releasing the long valve of check valve mechanism 142a to permit a full shot of metal as in Figure III; tube 3 first holds the time delay after tubes 1 and 2 have fired, and then when tube 3 fires, it resets tubes 1 and 2 (releasing their valves); when tube 4 fires, it unlocks die closing mechanism allowing dies to open—all as will hereinafter more fully appear.

Power input circuit—Figure VIII

The 3 phase inlet leads 90, 91, 92 are for a standard type of 3 phase motor 95', the motor which produces the oil pressure for the die operating mechanism and includes a branch lead 441 (from input lead 90) to a standard type of contactor shown bracketed at 442. Another lead connects 91 with contactor 442. A standard type of push button mechanism 443 is used to energize contactor 442, thereby applying power to motor 95' and also supplying 440 A. C. volts to relays 10', 11 and 12 to coils 30', 51 and 61.

A safety feature is here provided, in that if contactor 442 for any reason opens it removes the power from the main injection operating air valves 51 and 61 and oil valve 30', thus preventing squirting metal into the room. To do this, we provide power leads 445 and 446 in these coil circuits, lead 446 passing through the points of contactor 442 as shown. Thus, if contactor 442 is opened, then no voltage will be applied to coils 30, 51, 61, because the operating circuits to said coils will be opened.

Transformer circuit (from input leads 90 and 91) Figure VIII

Connected with input leads 90 and 91 we first provide fuses 450 and 451 and leads 452 and 453

to the switch points of another contactor having coil 456 having transformer 457 and outlet points 458 and 459. This energizes transformer 457 and a secondary voltage (24 volts) from transformer 457 is applied to coil 456 through switch 454 by leads 459 and 460. Then, by leads 461 and 462 voltage is applied to a main tapped transformer 465 which has a 440 volt primary and a 220 voltage secondary tapped at 110 volts to give another or third reduced circuit voltage of 110 volts. A circuit ground lead 467 is grounded at 468.

Tube supply circuits—Figure VIII

We provide a 220 volt circuit from transformer 465 (said circuit to be hereinafter further described) for the purpose of supplying current to the plates of thyratron tubes 1, 2, 3, and 4, and also through an additional transformer to the 24 voltage control circuit.

We also provide a 110 voltage circuit from transformer 465 (said circuits to be hereinafter further described) to supply another transformer for lighting the filaments of tubes 1, 2, 3, and 4 at 6.3 volts and another circuit for a heat control instrument hereinafter also described; this also includes 5 volts for a rectifier tube and a high voltage for the plate of the same to supply D. C. current to the grid bias circuits for the main thyratron tubes 1, 2, 3, and 4.

The 110 volt circuit from main transformer 465 includes fuse 469, lead 470 to normally open point 474, lead 472 to connecting point 473, which supplies through lead 545 the 110 volt primary of transformer 475. The 110 volt circuit from main transformer 465 also has lead 476 connected to lead 479 from said transformer, said lead 476 extending to terminal 477 to supply 110 volts for gas supply and heat control.

Details tube supply circuits—Figure VIII

Referring now to the above mentioned 220 volt circuit from transformer 465, the same includes fuse 480, lead 481 to primary of transformer 482 (TR2). The other side of the primary of said transformer 482 is grounded at 468 from lead 483.

The 24 volt control circuit

This transformer 482 has a 24 volt secondary winding with lead 484 to a terminal point 486 and by lead 487 through coil 406, the other side of coil 406 having lead, lead 489, to terminal 490, hence to switch 491 (normally open) to terminal 492, lead 493, and lead 485 to other side of transformer 482. Thus, when switch 491 in this circuit is closed, coil 406 is energized and this closes switches to effect an application of voltage to the system for automatic operation of the machine. Therefore, switch 491 is a key switch by means of which the mechanism may be disconnected from all automatic operation and, in certain instances, the machine may be operated manually.

This 24 volt control circuit also connects through lead 484, lead 494, to both points 495 and 496 of relay 430.

Relay 430 is provided to give a delaying action to application of 220 volts to the plates of tubes 1, 2, 3, and 4 and to the control circuit (above described) for relays 402 and 412, to allow tubes to warm up. This delay action is accomplished by a mercury time delay mechanism of Figure VII. Relay 430 does actual work of switching.

The 24 volt circuit is also connected to control relay 430 by lead 486 through point 499 of relay 499 and by lead 497, lead 498 to the coil of relay

430. The other side of coil 430 is connected by lead 485 to transformer 482.

The plate circuits for the tubes includes the terminal 468 as a common grounded cathode circuit from transformer 465. On the other side from said transformer, the plate circuit includes the fuse 480, lead 500, to normally open point 501 on relay 406 when point is closed in the automatic position of the apparatus. From point 501 we provide lead 502 to normally open point 503 on relay 430 also closed in the automatic position after time delay for the tube warm up has taken place (hereinafter described). Lead 505 from point 503 connects with terminal 506, all tube plate circuits connect from terminal wire 506. Thus, for tube 1, we have a lead 507 connected to lead 506, resistor 508 to limit the current flow, lead 509, to coil 510, lead 511 to the plate of tube 1. The cathode circuit of tube 1 is grounded as indicated by a circuit 513. We also have a condenser connected across coil 510 to supply current to coil on the negative $\frac{1}{2}$ cycle and prevent chattering.

The other tubes 2, 3, and 4 are similarly connected.

Thus, for tube 2, lead 514 is connected to the lead 506 common to all of tubes 1, 2, 3, and 4, as indicated supra. Lead 514 connects through resistor 515, lead 516, to coil 596, hence by a lead to the plate of tube 2 as shown. A condenser 519 is connected across leads 515 and 517, as shown.

For connecting tube 3, we provide a lead 520 passing through the resistor 521 to lead 522, which connects with coil 600 having lead 524 connected to the plate of tube 3. A condenser 525 is connected across leads 522 and 524. The cathode circuit of tube 3 is grounded as indicated by circuit 526.

For tube 4, we also provide a lead 530 connected with a common connecting lead 506, limiting resistor 531, lead 532, coil 412, lead 131, to the plate of tube 4. We also provide a condenser 535 across leads 532 and 131 as in the case of the other three tubes. The cathode of tube 4 is also grounded by circuit 537, as indicated.

Bias circuits

The bias circuit for each of tubes 1, 2, 3, and 4 will now be described.

110 volts from the main transformer 465 through relay 406 connects by lead 472, point or terminal 473, which is connected by lead 545 to the primary of the transformer 475 and returns by 546 to ground as shown at 547.

The transformer 475 has three secondaries, one 550 for the 6.3 volts for the filaments of the tubes 1, 2, 3, and 4. (Tubes are thyratron.)

Another secondary output circuit of 5 volts is indicated 551 for the rectifier tube 553.

The third center tapped winding 554 is for supply voltage to two circuits, one the plates of a rectifier tube 553 and the other for the main thyratron tube bias circuits. We have grounded the filament (cathode) of rectifier tube 553, as shown. At the center tap of secondary 554, we have a lead 555 to resistor 556, lead 557 combined choke and relay coil 499. From lead 557 we also have a lead 558 to condenser 559, the other side of which is grounded as shown.

From coil 499 we have lead 560 to the cathode of voltage regulator tube 561, the plate of which is grounded as indicated. Across tube 561 is a resistor 562 connected by lead 563 to lead 560 to

said tube 561, the other side of resistor 562 being grounded.

Our connections for these tubes also forms a time delay for the warming up of tubes 1, 2, 3, and 4, since relay 499 has a time delay on the make of points 499' with a well known type of switch which has quick break.

Moreover, this relay 499 provides a safety arrangement since failure of any part of the bias supply will cause 499' to open, dropping out relay 430 which disconnects the plate circuits of the tubes 1, 2, 3, and 4. This also drops out the 24 volt control circuit to the automatic operation.

Connections for the bias supply voltage and tubes 1, 2, 3, and 4

The above circuits and the tube 553 and 561 provide means to produce the bias voltage for the main thyratron tubes 1, 2, 3, and 4. We will now describe its connection to these tubes. Thus, we have a main bias supply lead 565 joined to lead 563 as shown, which lead 565 connects with three points (normally closed) on relay 566, points 567, 568, and 569. Lead 565 is also being connected with the points of relay 600, namely points 570, 571, 572, and 573. This lead 565 also has a connection to lead 575 to a contact 576 of relay 510. Lead 565 is in the main bias supply line for all four tubes.

For tube 1, bias is normally supplied from lead 565 to point 567, lead 577, resistor 578, the lead 579, to the grid of tube 1.

For tube 2, the bias is from point 568, lead 580, resistor 581, lead 582, to the grid of tube 2. For tube 3, the bias includes lead 583 from point 569, to resistor 584, lead 585, to the grid of tube 3.

For tube 4, the bias includes a lead 587 from point 573 to resistor 588, lead 589, to the grid of tube 4.

Sequential firing of tubes

We have provided means for causing tubes 1, 2, 3, and 4 to "fire" in sequence one after the other, and moreover, any subsequent tube in the series cannot "fire" until the preceding tube has fired. The circuits and means for accomplishing this will now be described. Thus, when relay coil 566 is energized, this opens points 567 and 568 and 569 removing bias from tube 1. The bias for tube 2 is now supplied only through an auxiliary circuit including a connecting lead 575 extending from lead 565 to switch point 576, lead 590, lead 580, resistor 581, lead 582 to grid of tube 2. When tube 1 fires (at the end of its time delay, to be described) relay 510, through lead 511, is then energized and normally closed point 576 now opens, removing the bias from tube 2.

Also, the firing of tube 1 and energizing of coil 510, closes the normally open point 592 thereby applying 24 volts to the power relay 12 by leads 637 to valve 51 to operate the metal injection at reduced pressure as will be pointed out.

Firing of tube 2

At the expiration of the time delay for tube 2 tube 2 fires (bias being removed by tube 1, as stated supra). This action opens normally closed point 595 of relay 596 which removes bias from tube 3, energizing coil 596 and also closes normally open point 597 which, through lead 598, energizes relay 11 for operating the check valve mechanism 61 to give the full shot, as will be pointed out.

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Firing of tube 3

Removing bias from tube 3 allows tube 3 to fire at end of its time delay energizing the coil of relay 600, closing normally open points 570 and 571, reapplying bias to tubes 1 and 2, thus resetting these tubes and their associated plate circuit relays.

Firing of tube 4

Moreover, normally closed points 572 and 573 are opened and since 572 is opened, this prevents reapplying bias to tube 3 by tube 2 at this point of the cycle. The opening of 573 removes bias from tube 4.

When tube 4 fires at the end of its time delay, the relay 412 is energized, opening normally closed point 413 which breaks the holding circuit for the die operating mechanism, above described. This holding circuit being removed, coil 30' is deenergized, and this permits the dies to open by a spring return of the die actuating control mechanism.

Time delay circuits for tubes 1, 2, 3 and 4

Referring to tube 1, we have a circuit which includes lead 577 (bias supply lead for tube resistor 578) lead 579 to grid of tube 1. When normally closed, point 567 opens, there is a circuit through resistor 578, lead 579, which also charges condenser 660 which bias is removed, supplies a voltage to grid 1 until it is discharged through adjustable potentiometer 661 and current limiting resistor 662 to ground 513 as shown. The other side of the bias circuit and tube cathode is grounded as described supra. Thus, the setting of the adjustment on potentiometer 661 determines the time for discharge of condenser 660 which, when it reaches critical grid voltage of tube 1, allows the tube to fire. Resistor 662 limits the current for a very low or offsetting of the potentiometer 661. Resistor 578 has two purposes, one to prevent main bias supply from being shorted in case condenser 660 fails. Also it provides a buffer action to prevent burning of point 567, due to sudden inrush of current to condenser 660. It will be understood that we have provided similar potentiometer time control discharge networks for each of the other tubes 2, 3 and 4 and in the drawings we have used the same numerals as for tube 1.

Reapplying bias to tube 3

The bias control of the tube 3 (and also 1 and 2) is interlocked with the microswitch 602 which switch, in turn, is actuated by the rack on the machine, which rack is operated by the hydraulic system for the die operating mechanism. The microswitch also has point 603 (normally closed). Closing of point 602 by said rack or machine operated part closes relay 605. This is accomplished by circuits connected with power input relay 430 which includes lead 408; with contact 496 of relay 430, and leads 409 and 606. Another lead 607 also connects from 606 to a point 608 (normally open) of relay 412.

On the other side of coil 605, a lead 610 connects with normally open side of microswitch 602, referred to supra and lead 611, leads 652, 424 and 425, normally open point 426 on relay 430.

When coil 605 is energized, coil of relay 566 is also energized. Relay 605 has three normally open points, 612, point 613 and 614. The connection from relay 605 to relay 566 includes point 612, lead 615, relay coil 566. From the other side of relay 566, lead 616 connects to lead 419, point

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418 of relay 402, the other side of the switch 418 has a lead 417 extending to terminal 416, lead 418 has a lead 417 extending to terminal 416, lead 618 through safety point 619 of 640 open button (normally closed) which also connects to lead 620 and connection 621, lead 623, which connects to lead 606, completing the circuit for energizing coil 605 and hence, coil 566. Energizing coil 566 opens all three points 567, 568, and 569, which removes bias from tube 1 and allows it to be removed in sequence from tubes 2 and 3, and the bias to tube 3 is reappplied by point 569 of relay 566 when relay 566 is deenergized as the machine opens by breaking the microswitch at point 602. In the meantime, bias on tubes 1 and 2 has been restored when tube 3 fires, as stated supra.

Pressure switch control for preventing machine from opening when metal is being injected into dies

We provide a special safety control in connection with preventing metal injection when the dies are open and also an improper action in case the operator accidentally presses control part.

Thus, from relay 406 (to which current is supplied from transformer 482) we provide a circuit from point 625 of relay 406 to a pressure switch 628 by leads 409, 408, 651, 652, 424, point 613 of relay 605, lead 629, to pressure switch 628. This pressure switch 628 is located across the die open and closing control circuit in such a way as to prevent the machine opening, but cannot accidentally close it. When the machine is in automatic control position, relay 430 is energized thereby closing points 496 and points 426, as stated supra, and 24 volts is supplied through point 496, lead 408, 409 to normally open point 625 on relay 406 and in the automatic position, this point 625 is closed, allowing voltage then present at point 625 to pass through lead 410 to coil of relay 10 to coil 30. The other side of relay 10 by lead 407 connects with a normally open point 626 (closed in automatic position), lead 629 to point 613 of relay 605. From relay 605 the other side of 613 connects by lead 424 to return control voltage lead 425, point 426 of relay 430 supplying energy at 24 volts from transformer 482.

Safety circuit for preventing pressure switch from closing the machine—Pressure switch merely holds machine closed while metal is being injected

Point 613 on relay 605 is primarily for connecting pressure switch 628, which is an electrical contact on a pneumatically operated mechanical pressure switch in such a manner that the pressure switch, while it may hold the machine closed as long as air pressure exists on switch 628, yet if air pressure is supplied accidentally, such action will not result in the closing of machine from an open position since relay 605 must be energized to hold point 613 closed before the pressure switch can be effective to supply energy to the coil 10 (die closing) if switch point 613 is open, such connection will be broken. The microswitch point 602 controls relay 605, and the machine must be closed before 605 is energized. Hence, if the machine is not closed, 605 is deenergized and point 613 is open so that no energy can be supplied to coil 10.

Pilot light circuit

When pressure switch 628 is closed, we provide a signal light 630 to show that the pressure switch

is operating. Thus, we connected to the 24 volt control circuit by point 496 of relay 430, lead 408, lead 631, to lamp 630 and from lamp 630 by lead 632 to pressure switch 628, through pressure switch lead 629, point 613 of relay 605 and returning through lead 424 to point 426 of relay 430.

Circuit to prevent relays 11 and 12 from contacting until dies are closed

When microswitch 602 is closed, this energizes relay 605, and hence closes points 612 and 613 and 614 as indicated supra. When point 614 closes, we have a safety circuit from point 614 which is connected on one side to lead 424 to 24 volt pilot circuit. From relay 605 at the other side of point 614, we provide a lead 635 which connects to relay coils 11 and 12 in series. Referring to coil 11, we have a lead 598 connected to point 597 of relay 596, through said point 597, leads 409, 408 to the other side of the 24 volt circuit at point 496 of relay 430.

This safety circuit just described, also controls relay 12. Thus, from lead 635 (for relay 11) we also have a lead 636 to relay 12, and from relay 12 by lead 637 we connect to point 592 of relay 510 through point to lead 408 hence to point 496 of relay 430.

Thus, it will be seen that both relays 11 and 12 are interconnected in the system so that these relays cannot be closed when the dies are opening, since relay 605 would be open, and hence point 614 would be open and break the circuits for both relays 11 and 12. Thus, if tubes 1 or 2 fired, due to a fault, then relays 11 and 12 would not operate to inject metal into the dies.

Microswitch must be in correct position

We have a further circuit to correct a condition, when in operation microswitch 603 becomes jammed in position requiring an injection of metal into the die. This additional circuit acts as a safety circuit to prevent such an improper injection of metal in case operator presses close button. When operator presses close button point 640 of the switching connections indicated at 23' to start automatic cycle voltage control, through point 619, safety button point 649, lead 641, through safety point 603 of the microswitch, lead 400 to coil 402, which completes the closing circuit for coil 402, this closes the machine. However it will be seen that if point 603 is in metal injecting position, the operator will not be able to close the machine, since point 603 would be open if the microswitch is not in its normal position for the start of the cycle.

Safety circuit to prevent machine operation by accidental closing of microswitch

We also have a normally closed point 603 of the microswitch connected in such a manner as to prevent operator from closing the machine if the microswitch is jammed. If point 602 of microswitch is closed accidentally, unless at correct normal position, relay 402 has not been energized leaving point 419 normally open. Relay 566 and associated points 567 and 568 are actually the controlling points for the two stage metal injection through coils 11 and 12. Thus, if microswitch is accidentally closed, causing relay 605 to close, starting shot cycle, relay coil 566 will not be energized even if point 612 of relay 605 has closed, because the other side of coil 566 has its circuit broken, by normally open point 418 which will not be closed unless machine is in

normally operating cycle by action of the automatic close button 640. The manually controlled automatic station and the microswitch control circuits are therefore dependent upon each other as indicated.

Emergency switch for stopping automatic action and causing machine to open and mechanism to be reset

In the automatic operation of one complete cycle of the machine, the relay 402 acts as an electric self "locking in" means for effecting the supply of current to the various circuits heretofore described. As will be seen from Figure VIII and the foregoing description, this current supply is a 24 volt circuit which includes lead 620 on one side and 424 on the other. We also provide, however, an emergency switch in the form of a momentary contact 619 which is normally closed, but which may be opened to break this locking in circuit. Referring to the drawings, this is accomplished as follows:

The 24 volt circuit referred to flows from lead 620 through the normally closed, momentary breaking, safety button 619, through lead 618, point 418, lead 417, to relay 402. This relay 402 is energized when the machine is operating in which case point 418 of this relay 402 will be closed. Thus, current from lead 620—417 passes through point 418, lead 419, to point 413 of relay 412, through this point, through leads 415 and 400, to the coil of 402, through the coil of 402, back to lead 424, which is the other side of the 24 volt supply. Since the locking in 24 volt circuit for relay 402 is supplied between the leads 424 and 620, and this emergency safety button 619 is interposed between these two leads, it will be seen that when the operator opens the switch 619, the locking relay 402 is released and the shot cycle resets and the dies of the machine open.

Pilot light for heat control instrument

We also have a heat control pilot light 645 in a circuit to the 24 volt transformer 482 connected on one side through leads 484, 486, 497, lead 646, light 645. From the other side of light 645, we have a lead 647 to leads 492, 493 and lead 485 to the other side of transformer 482. Thus, when the heat control on and off switch 454 is closed (which is a toggle switch) it energizes relay 456 through leads 459 and 460 applying 440 volts to transformer 465 (primary) to supply 110 (secondary) for the heat control motor and gas valve (not shown). Also, this energizes transformer 482 from the 220 secondary of transformer 465, which supplies 24 volts to the pilot light 645 through the circuit, just described supra. When switch 454 is closed, it applies 24 volts to the pilot lamp 645 showing the operator that the heat control and gas valve section of the cabinet is on. Relay 456 has a transformer 457, the control circuit of which is 24 volts supplied by said transformer from the 440 volt circuit. This avoids the necessity of supplying 440 volts at any time to the control section of the cabinet.

Pilot lamp for indicating machine ready for automatic action

We also provide a lamp 650 connected by lead 551 to lead 408, hence to point 496 of relay 430. On the other side, lamp 650 is connected by lead 652 to lead 425 to point 426 of relay 430. Operator closes switch 491, thereby energizing relay 406 throwing the circuits into automatic posi-

tion. This energizes bias transformer 475 and connected circuit, which at the end of its time delay (allowing tubes 1, 2, 3, and 4 to warm up) closes point 499' of relay 499 energizing relay 430. This applies the 24 volt control circuit across pilot lamp 650 and also supplies 24 volts to the automatic control section and hence shows the operator that the tubes 1, 2, 3, and 4 have been heated sufficiently for operator to close button 640 to start machine in automatic operation, but there is no control voltage on the automatic section until this above mentioned time delay has expired.

Manual control circuit

We have a manual automatic switch 491 operable when relay 406 is not energized. The control by switch 491 is dependent on switch 665. Thus, if manual switch 665 is closed, 24 volt control voltage from transformer 482 will flow through lead 485, lead point 666 of relay 430, lead 667 to the manual open and close switch 665, lead 668, point 669 (closed) through the lead 487 to the coil of relay 10' for the die operating mechanism. The return circuit is through lead 410, point 670 (closed) lead 671, to point 495 (relay 430), lead 494, lead 484, to other side of control transformer 482. Thus, when the mechanism is in manual position, determined by the position of switch 491, and switch 665 is closed, 24 volts is applied across the coil of relay 10', operating pilot valve 30' to open and close dies of machine but the rest of machine, including metal injection, will not operate.

Résumé of circuits—Figure VIII

From the foregoing, it will be seen that we provide the following main circuits and controls:

(1) POWER INPUT CIRCUIT

Through leads 90, 91, and 92, we supply three phase alternating current, 440 volt current, to the power panel of our combination power panel and electrical control mechanism.

(2) TRANSFORMER AND VARIOUS TRANSFORMER CIRCUITS

We provide a preliminary transformer 457 and connecting circuits therefor; the main transformer 465 for providing circuits for 220 volt and 110 volt; 24 volt control circuit transformer 482; and the bias circuit transformer 475 all with inter-related circuits, as herein appears.

(3) MACHINE OPERATING CIRCUITS

From the foregoing, it will also be seen that we provide a 440 volt circuit for the main machine operating electrical means including the motor 95' for producing oil pressure to operate the die closing mechanism, the coil 30' for operating the electric control for die closing, and the coils 51 and 61 for the two stage metal injection operating means.

(4) CONTROL CIRCUITS

We provide several interrelated and interconnected control circuits to properly effect the application of the foregoing machine operating circuits just referred to. These control circuits are supplied with current at 24 volts and primarily are for operating the coils 10', 11, and 12 to in turn effect an operation of the die closing mechanism and the two stage metal injection referred to. These control circuits are basically controlled by the thyatron tubes 1 and 2 (tubes 3 and 4 being for resetting). We also provide a

control for effecting an operation of the circuit to the oil pressure motor 95' through contactor 442 through push button stage 443. Each of these circuits includes the various relays as hereinbefore set forth, a complete operation following this list of circuits. The supply of control voltage to coil 10' is primarily through relay 482 when the automatic system has been put into operation through the close button manually operated switch 640. For energizing coil 51 by means of control coil 12, we provide relay 510 connected in the plate circuit of tube 1 for effecting this result. For operating coil 61 through control coil 11, relay 596 in the plate circuit of tube 2 produces this action.

(5) SAFETY CIRCUITS

We provide two solely safety circuits in the switch point 663 of the microswitch, if the latter is not in the correct position, as indicated supra, under the sub-title, Microswitch Must Be in Correct Position. We also provide another solely safety circuit in the connection through the switch point 614 of relay 605 to prevent the operation of the metal injection in case the dies are not closed, as described supra under the sub-title, "Circuit to Prevent Relays 11 and 12 From Contacting Until Dies Are Closed."

(6) PILOT LAMP CIRCUITS

From the foregoing description, it is also clear that we provide pilot lamp indicators to advise the operator of the machine the various conditions as referred to in describing said pilot lamps.

Operation—One complete cycle

As heretofore indicated, the machine is started by the operator closing the quick return close button 643, one side of which is connected to the power inlet and through leads and switches to "locking in" relay 482, hence, relay 486 and correlated circuits and controls to the relay 430 which is connected with the 24 volt transformer 482 to supply current thereto, through the various circuits, heretofore described and clearly shown in Figure VIII, which causes the coil 10' to close the power circuit through the operating coil 30'. This action will close the dies of the machine as indicated in Figure I.

As the dies are closed, the microswitch is operated by a part of the die closing mechanism to thereby throw the microswitch to close 602 position and effect an energization of relay 605. The machine is held by a mechanical action of a toggle mechanism disclosed in the Schultz et al. Patent No. 2,173,377, referred to supra. Relay 605 closes switch point 612 and relay 566 is energized, opening point 567 which is in the bias circuit for tube 1, as described supra. Opening the tube 1 bias, permits tube 1 to fire at the end of its time delay through its plate circuit, thereby energizing relay 510, closing switch point 592, as stated supra. This, through the various circuits, above described, energizes relay 12, which, in turn, supplies power to the pilot valve for the main air cylinder 51, permitting a delayed shot of metal at reduced pressure to be injected into the die as the first part of the two-stage metal injection at the reduced pressure on the metal as above indicated. Specifically, closing of switch point 592 by the discharge of tube 1 connects leads 488 to point 496 of relay 430, point 496 being normally closed, hence to lead 484 of the 24 volt transformer 482 and back to switch point 592 of relay 510 which connects the current to

lead 637, and as clearly shown in the drawing, to relay 12. The other side of this relay circuit includes lead 636, 635, to point 614 of relay 605 (now closed through 614, lead 424, 425 to switch 426, lead 485 to transformer 482).

The firing of tube 1 energizes coil 51 and causes the action illustrated in diagram of Figure II of the drawings, in which the dies, having previously been closed, solenoid air valve 51 permits movement of the piston 332 and the correlated parts, illustrated in the diagram of Figure II, as described supra, permits a slow injection of metal by a slow movement of piston 32a at a relatively low pressure of the metal and all air beneath the piston 32a is removed by the adjustment of valve 84a, as described supra. This is an important feature of our invention since we have found that by removing all of the air beneath the piston 32a, when the next cycle of operations takes place, it permits a very strong satisfactory injection of main metal into the dies avoiding complicated arrangements heretofore regarded as necessary.

Temporary auxiliary circuit for biasing tubes 2 and 3

It will be noted from the wiring diagram of Figure VIII that we also provide in addition to the main biasing circuit above described an auxiliary bias circuit for tubes 2 and 3. To this end it will be noted that we provide a lead 575 from main bias supply lead 565, lead 575 connected through normally closed point 576 of relay 510 and lead 590 to the bias circuit 580, etc., for tube 2. This auxiliary circuit for tube 3 we provide in an additional lead 572' extending from point 572 of relay 600, hence by lead 595' to lead 583 which connects to the bias circuit of tube 3. This auxiliary biasing circuit for tubes 2 and 3 is on temporarily simultaneously with the main bias supply described above.

Firing of tube 2

It will be noted as indicated above, when relay 566 has been energized the main supply bias at switch points 568 and 569 have also been broken at the same time when the bias supply was broken to tube 1. However, the auxiliary bias supply circuits for tubes 2 and 3 still prevents tubes 2 and 3 from firing.

By the firing of tube 1, just described, this auxiliary bias for tube 2 is also opened because switch point 576 which is in the bias circuit for tube 2, has now been opened by relay 510. Removing tube 2 bias causes the discharge of its circuit at the end of its time delay, and energizes relay 596. Thus, when point 597 is closed, current is supplied from the transformer 482 to relay 11 circuits and switches, since we have provided a lead from the lead 408, numbered 409, to switch point 597 (lead 408 being connected to transformer 482 as just described) and from switch 597, lead 598 to relay 11. On the other side of relay 11, we have a lead which joins lead 635 just described. Hence, the connections are established back to the transformer 482, as just described in connection with tube 1. As will be understood from the foregoing, the energization of relay 11 in turn connects the 440 volt power line to the coil 61 of the air pilot valve which causes the main injection of metal at high pressure into the closed die since it effects opening of large valve of the valve mechanism 142a consequently producing the high pressure on the

molten metal, all as illustrated in Figure III of the drawings.

Holding the pressure of the metal in the dies, known as set time

An important feature in our invention is the correlation of the electric controls herein described, which at this point in the cycle of operations, permits the apparatus to remain in the position it is in when the step illustrated in Figure III is completed and the piston 32a has reached the bottom of its stroke carrying with it the metal injection piston, illustrated diagrammatically thereunder. The apparatus is now held in this position with the pressure on for a desired length of time called set time. The time delay in the bias circuit through the potentiometer 661 of tube 3 prevents its discharging until the metal has set in the die as described supra.

After set time, firing of tube 3

Next in the cycle of operations, we provide means through the firing of tube 3 to reset the bias circuits for tubes 1 and 2. This is done by establishing a temporary additional biasing circuit hereinafter described. The resetting of the bias of tubes 1 and 2 is done primarily by first removing the above described auxiliary bias from tube 3 by opening the switch point 595 of relay 596 which, as stated supra, occurs when tube 2 fires. Removing the bias from tube 3 therefore causes a discharge after the time delay shown, as will be understood, through its plate circuit. Firing of tube 3 energizes relay 600 which is in the plate circuit of tube 3, as shown so that energization thereof closes switch point 570 and 571, which are in an additional temporary bias circuit which, as shown in the drawings, includes main supply line 565 which is connected through the now closed switch points 570 and 571, point 570 connected to the bias of tube 1 through 570' and 571 while the temporary additional bias for tube 2 is connected through point 571, lead 571', lead 580 connecting to the bias of tube 2. By closing these switch points 570 and 571, tubes 1 and 2 are rebiasing through these additional circuits just described. It is understood that when the proper bias is applied to tubes 1 and 2 discharge thereof through the plate circuit ceases.

Prevention of rebiasing of tube 3

To prevent rebiasing of tube 3, we have also provided another switch point 572 for relay 600 so that when relay 600 is energized, as just stated, this switch point 572 opens with the result that reestablishing bias through the additional circuits just described to tubes 1 and 2 will not also re-establish through the auxiliary circuits bias to tube 3.

From the foregoing, it will be understood that when bias is re-established to tubes 1 and 2, these tubes cease firing and coils 11 and 12 are de-energized, permitting solenoid operated pilot valves 51 and 61 to be returned to normal position. After tube 3 has fired, the apparatus is in the position illustrated diagrammatically in Figure V in which the pressure has been removed from the metal in the dies and a period of time, called the cooling time, is allowed for the metal to cool, which is the time preceding the firing of tube 4 in our electrical circuits the "cooling" time being controlled by potentiometer 661 of tube 4.

Firing of tube 4 opens the dies machine and circuits thereby reset to initial position

Firing of tube 4 accomplishes the re-opening of the dies. Referring back to tube 3, it will be noted that when it fires, it has opened switch point 573 on relay 600 which, in turn, removes the bias from tube 4 after its time delay through its potentiometer circuit 611, tube 4. When the bias on tube 4 is removed, then the tube discharges, energizing coil 412, opening point 413 on relay 412, thereby breaking the holding circuit for relay 402 which drops out relay 402. Since, as described above, it is the energization of locking in relay 402 which closes the dies, the opening of the circuit thereof permits the apparatus to complete the cycle and return to the position shown in Figure VI with the dies opening, moving to the full open position shown in dotted lines. Mechanical means, such as spring X, returns valve 63a to initial position.

Automatic rebiasing of each of the tubes after mechanically completing one cycle of machine operation

When relay 402 is de-energized, as stated supra, effected by the firing of tube 4, then relays 605 and 566 are also both de-energized. This closes the switch points 567, 568 and 569 so that now bias is resupplied to both tubes 3 and 4 as well as to tubes 1 and 2. This is due to the fact that the bias supply line 565 as indicated supra is connected with points 567, 568 and 569 controlled by relay 566 and under normal inoperative position of the machine the closing of these points closes the bias circuit through lead 577 to tube 1, the lead 580 for the bias circuit to tube 2, the lead 583 for the bias circuit to tube 3. It will be also noted that the main bias supply lead line 565 is connected with relay point 573 of relay 600 and since this point is now closed, lead 587 supplies the bias to tube 4. Point 573 is closed because of the fact that tube 3 has now been rebiasing and therefore relay 600 has been de-energized and spring means closes the contact 573. Rebiasing tube 3 in this manner thereupon permits its relay coil 600 to effect opening of points 571 and 570, thereby disconnecting the additional bias circuit which was temporarily established for tubes 1 and 2. The entire electrical apparatus is now in initial position. The machine then will not recycle until the operator restarts the cycle by pressing manual close button 649, as described supra.

Interconnection control for supply of bias and plate circuits of tubes for warm up time and to open plate circuits upon failure of bias supply

It will be noted that we have an important interconnection in the circuit arrangements so that before the machine can be operated, there is a warm up time for the several thyatron tubes and also an interconnection, so that if the bias should fail, due to abnormal conditions, such failure opens the main plate circuits of the several tubes so that they would not discharge, as otherwise this would cause an improper operation of the die casting machine. Circuit 550 is for the heaters of the thyatron tubes.

The transformer 475 provides a 5 volt circuit 551 for the filament of the rectifier tube 553. Also the bias circuit for the several thyatron tubes 1, 2, 3, and 4 is supplied from transformer 475 (changed to D. C. by rectifier tube 553) the

bias circuit including center tap winding 554, lead 555, voltage reducing resistor 556, branch circuit, lead 558, filter condenser 559, which is grounded as shown. The outside of said winding 554 is connected to the plates of rectifier tube 553, the filaments thereof also grounded as shown. (The cathode circuits for each of the thyatron tubes are likewise grounded.) Resistor 556 also has a connection through main lead 557 to the coil 499 which, being in the bias circuit, as stated above in the description, and shown in the drawings, is also arranged to act as a combined choke and relay, the point 499' being of the type which is slow making and quick breaking. Connected to the coil 499 by lead 560, which connects by lead 563 to the main bias supply line 565 for the main thyatron tubes, we also provide a further regulating means in the regulating tube 561 which is grounded as shown. Moreover, across the tube 561, a resistor 562 is further employed to control the circuits, resistor 562 being grounded as shown.

The switch 499' of coil 499 is as shown in the control circuit for the plate voltage of the several thyatron tubes, so that upon energizing relay 499, the slow closing of the plate circuit through switch point 499' gives the tubes a chance to warm up in their internal circuits before the plate voltage supply is connected to said tubes. Moreover, as stated supra, if there is any failure in any of the bias supply circuits for the tubes, since the same passes through relay coil 499, and this must be energized to close switch 499' in the plate circuits of the tubes, failure of the bias circuit opens the relay point 499', and hence disconnects the plate supply circuits to tubes 1, 2, 3, and 4.

Manual control for operating opening and closing of dies and circuits

In order to permit the operator to open and close the dies, at will, without the rest of the machine operating, as may be necessary, we provide an independent circuit manually controlled, which operates merely the coil 10 for operating the die closing mechanism.

Thus, we provide a manually controlled switch 665, which is a circuit extending from the transformer 482 to energize coil 10 independently of the automatic controls described above, said circuit being established to the power input or disconnected therefrom according to the position of the manual-automatic changeover switch 491. For one side of manual switch 665, we provide a lead 668 and a lead 667, which extends to points 666 on relay 430 closed with the manual-automatic changeover switch 491 in the manual position. From switch point 666 of relay 430, lead 485 connects to the 24 volt circuit from the transformer 482. Then by lead 484, lead 494, switch point 495, lead 671, switch point 670 of relay 406, normally closed under these conditions to lead 410 to coil 10'. From the other side of coil 10', lead 407 connects to switch point 669 and from lead 668 to the other side of the main manual switch 665 just referred to.

In order to accomplish the foregoing, as indicated, we provide the relay 406 to isolate the rest of the machine so that this manual control may be operated. In order to accomplish this isolation, we provide the relay 406, whose energization is controlled from the manual automatic switch 491 so arranged that when this switch 491 is in the manual position, it de-energizes relay 406, and when in the automatic position it energizes this relay. Thus, we provide from relay 406,

lead 488 to 490, to a switch 491, lead 492, 493 to lead 485, transformer 482, lead 484, lead 487 to relay 406. It will thus be seen, if the manual automatic switch 491 is opened, 406 is de-energized and a control of the dies through the manual switch 665 may be accomplished. However, if the operator closes switch 491, the coil 406 is energized, and this will open the circuit from switch 665 to relay 10. Hence, even if the operator might manipulate the hand switch, no energy would be supplied to coil 10.

It is apparent that, within the scope of the invention, modifications and different arrangements may be made other than is herein disclosed, and the present disclosure is illustrative merely, the invention comprehending all variations thereof.

What we claim is:

1. A method of hot chamber pressure die casting employing pressures in excess of one thousand pounds per square inch comprising closing the dies to form a mold cavity, injecting a portion of the metal at a relatively low pressure on the molten metal and after the cavity has been partially filled completing the filling by injection at a pressure in excess of one thousand pounds per square inch.

2. A method of hot chamber pressure die casting employing pressures in excess of one thousand pounds per square inch, comprising closing the dies to form a mold cavity; injecting a portion of the metal at a relatively low pressure on the molten metal; completing the filling after the cavity has been partially filled by injecting the metal at a pressure in excess of one thousand pounds per square inch; holding the pressure on the metal in the mold until the same becomes set; withdrawing the pressure from the metal in the

mold and allowing the metal to cool before the dies are opened.

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