

June 25, 1946.

H. A. STRICKLAND, JR
INDUCTION FURNACE LOAD-CONTROL

2,402,852

Filed March 2, 1943

3 Sheets-Sheet 1

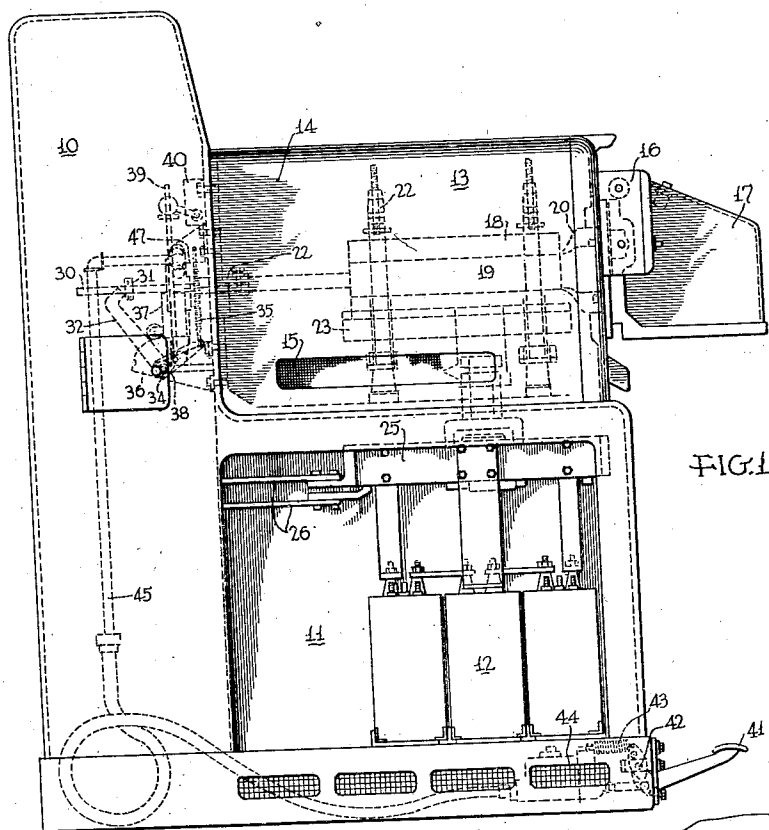


FIG. 1

FIG. 2

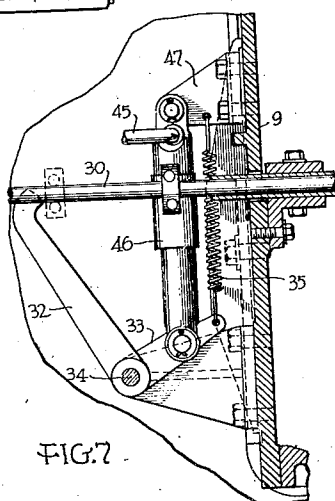
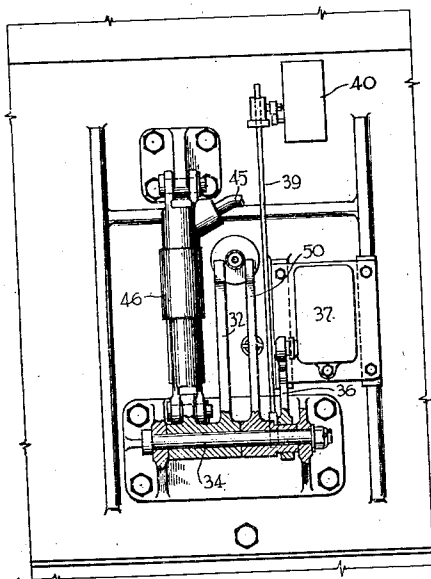


FIG. 7

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FIG. 3

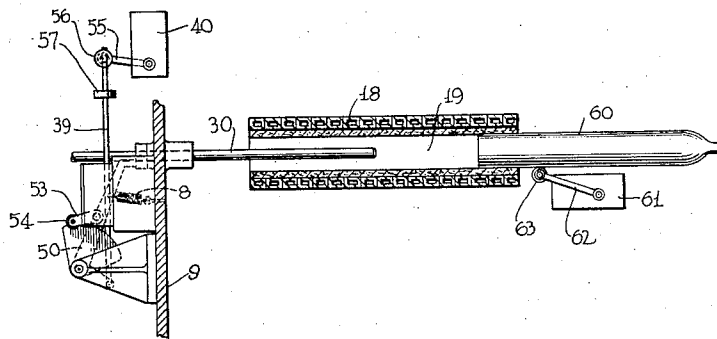


FIG. 4

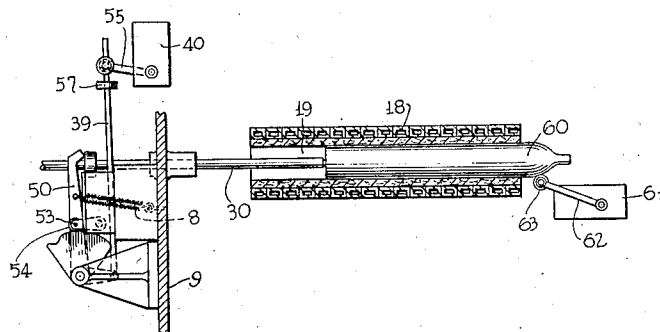
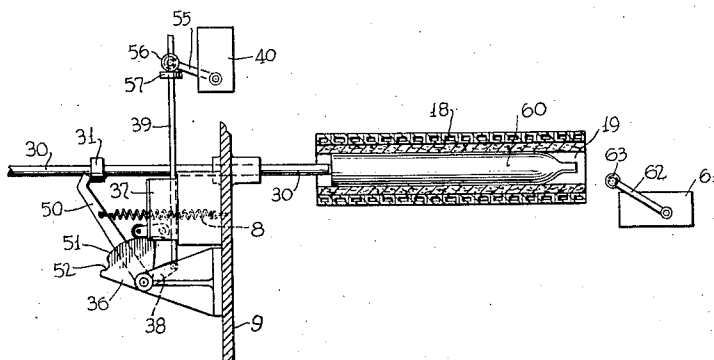


FIG. 5



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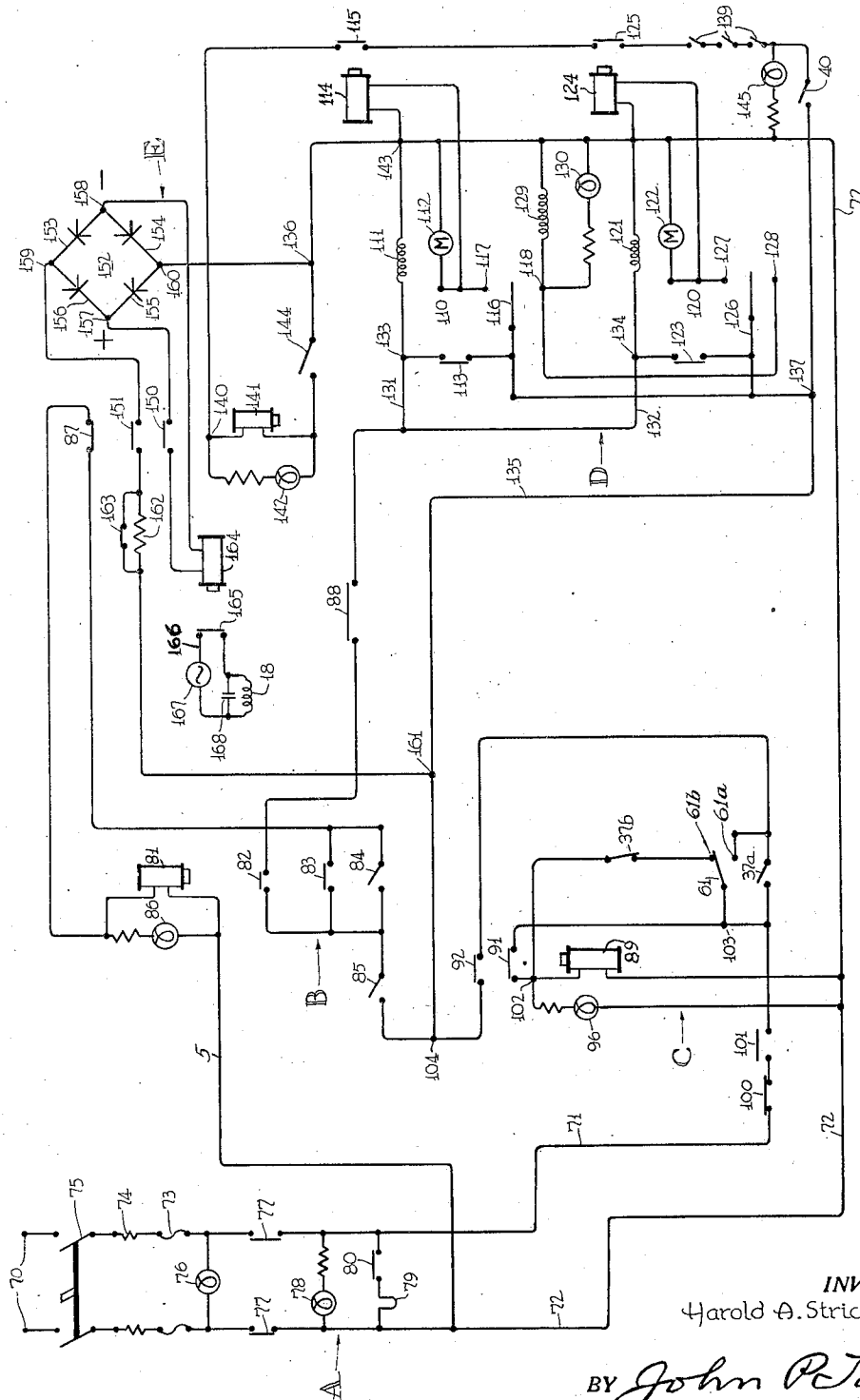
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INDUCTION FURNACE LOAD CONTROL

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Application March 2, 1943, Serial No. 477,749

9 Claims. (Cl. 219—13)

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This invention relates generally to induction furnaces, and more specifically to induction furnaces adapted to heat billet or bar stock for forging purposes. In such furnaces it may readily occur that due to various causes such as power failure to the control circuits, or operation of limit switches within the induction furnace control or by direct or accidental stoppage of the heating cycle circuits, the timers controlling the heating cycle of the furnace are reset. Consequently, if a new heating cycle is instituted without removal of a partly heated billet, the furnace may be damaged by melting of the billet.

It is, therefore, an outstanding object of the present invention to provide an induction furnace control requiring complete removal of a workpiece from the furnace in which the normal heating cycle has been interrupted. Another object is to prevent reheating of a workpiece after a normal heating cycle without first completely removing the workpiece from the furnace. An additional object is to provide furnace control means for preventing overheating or melting of a workpiece. An object also is to prevent operation of an induction heater unless the workpiece is completely inserted in the furnace.

The above and other objects are effectuated by the mechanism and procedures hereinafter described and illustrated in the accompanying drawings, in which

Fig. 1 is a side view of a furnace embodying the invention;

Fig. 2 is a rear elevational view showing details of the switch operating mechanism;

Figs. 3, 4, and 5 are diagrammatic views showing the workpiece entering, partly entered, and fully entered into the furnace chamber;

Fig. 6 is a wiring diagram of the electrical circuits; and

Fig. 7 is a section of the apparatus shown in Fig. 2.

The general physical arrangement of the furnace follows that of my co-pending application Serial No. 384,503, filed March 21, 1941, on which this invention is an improvement. As disclosed in said application and as shown in Fig. 1, the furnace includes an upright rear section 10 forming an L-shape with a front lower section 11, the section 10 containing control apparatus and, section 11, capacitors 12.

Placed closely in the angle of the L-shape is the furnace unit 13 having a casing 14, a ventilating screen 15, hood switch box 16 and hood or door 17. In dotted outline within the casing

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14 are shown the heating coil 18, heating chamber 19, mouthpiece 20, C-bracket furnace supports 22, and bus bars 23 having depending connections to the bus framework 25 and power inlet connection 26 in section 11. Furnace section 10 includes the ejector rod 30 extending into the furnace chamber as shown in Fig. 3, ejector collar 31, bell crank arms 32 and 33 on pivot 34, bell crank spring 35, bell crank cam 36, limit switch 37, bell crank arms 38, bell crank rod 39 and full load limit switch 40, these elements being mounted on the partition plate 9, separating the furnace section 10 and 13.

At the right hand base of furnace section 11 is illustrated a foot lever 41, pivoted at 42, which on actuation against tension of spring 43, compresses fluid in a servo-motor 44 thereby transmitting pressure through pipe line 45 to the floating fluid pressure piston-cylinder unit 46 shown in Figs. 2 and 7. The cylinder has pivotal connection to the bracket 47 to which the depending bell crank spring 35 is also attached. The piston of unit 46 is pivotally connected to the bell crank arm 33 so that on extension of the piston on pressure of foot pedal 41 the bell crank 32—33 is rotated to move the ejector rod into the furnace chamber 19, thus forcing outwardly the contained workpiece. Simultaneously the limit switch bell crank arms will follow collar 31 due to spring loading as will now be more fully described.

Reference is made to Fig. 2 for further structural details relative to the load switch operating mechanism. In this figure it appears that the pivot pin 34 for the pedal operated ejector bell crank 32—33 also supports bell crank cam 36 with its associated arm 50 and arm 38. While bell crank 32—33 is an integral unit, the position of cam 36 in the 50—36 bell crank unit is adjustable to control the point of operation of switch 37, this switch having a normally open switch contact element 37a and a normally closed switch contact element 37b.

As shown more clearly in Figs. 3—5, the cam element 36 has a circular periphery 51 terminating in a recess 52 on the far side from the furnace chamber. Adapted to move over the cam periphery is the switch arm 53 terminating in the arm roller 54. When the roller rests in recess 52 the limit switch 37 is in its open position. Rearward movement of the cam away from the furnace will lift the arm roller out of recess 52 thus closing switch contact element 37a and opening 37b. This movement is opposed by coil

spring 8, attached to arm 50 and back partition back plate 9.

The bell crank arm 38 of the bell crank unit 50—38 is fixed relative to arm 50, and at its end has pivotal connection to the rod 39 extending upwardly to a point adjacent load limit switch 40. This switch has an arm 55 carrying at its end a fitting 56, vertically apertured to receive the end of the upstanding bell crank rod 39. The arm 55 is pivotally mounted on the fitting 56 so that movement of the fitting on the rod operates the switch 40. A collar 57 is adjustably fixed to rod 39 at a predetermined distance from the lower rod pivot such that when the bell crank 50—38 is moved to its extreme rearward position the collar 57 will have engaged the fitting 56 and moved the arm of switch 40 to closed position. At the other positions of bell crank movement the switch 40 is open, as appears from Figs. 4 and 5.

Figs. 3, 4, and 5 show diagrammatically the relative position of furnace and load limit switch mechanism. The switches and controls are mounted on the rear of back plate 9 in operative relationship with the ejector rod 30 and the attached rod collar 31. On the front of back plate 9 the ejector rod 30 extends into furnace chamber 10, substantially axially thereof, and is thus adapted to contact with the bar 60 or other work-piece inserted through the furnace mouth 20. Adjacent and below the mouth is the single pole double throw load limit switch 61 having switch contact elements 61a and 61b and also having a spring controlled operating arm 62 and roller arm terminal 63, this terminal being adapted to engage yieldingly the work-piece while it is being inserted removed from the furnace chamber. This engagement is such as to cause opening of the normally closed switch element 61a closure of the normally open switch contact element 61b only when the switch arm 62 is forced downwardly by the workpiece the spring moving the switch arm to position to close 61a and open 61b as soon as the load moves out of contact with roller 63.

Having in mind the physical arrangement of furnace and switch elements, as shown in Figs. 3 to 5 particularly, the operation is as follows. Prior to introduction of the workpiece all load switch contact elements except 37b and 61a are in open position. Upon engagement of the workpiece with the arm of load switch 61, as shown in Fig. 3, contact element 61b is closed and 61a is opened. Further movement of the bar to the position of Fig. 4 brings about engagement of bar and ejector rod, thus moving out collar 31 to rotate cam 36 and close switch contact element 37a and open 37b. In the final position of Fig. 5, with the bar fully within the furnace chamber, cam rod 39 is at its uppermost position thus closing the switch 40. At the same time the mouth switch 61 is freed of workpiece engagement and 61b switch element is opened and 61a closed. It may be here observed that if the workpiece is over-long so as to keep switch element 61b closed when the workpiece is at the rear chamber limit, such closure will not interfere with the successful operation of the furnace.

Having described the physical features of the invention it remains to describe the electrical circuits, through the functioning of which the switches are controlled so as to require complete removal of a workpiece in case of accidental power stoppage due to causes within or without the furnace circuits.

The wiring diagram is shown in Fig. 6, the power source supplying alternating current being indicated at 70, and the main lines at 71 and 72. The circuits may be roughly classified in five sections designated as supply, starting, load safety, timer and high frequency and identified in the drawings as A, B, C, D, and E, respectively. The supply section A includes fuses 73, overload disconnecting heaters 74, and main switches 75. Included also are the main 60 cycle pilot lamp 76, water pressure switches 77, water pressure pilot lamp 78, water heater 79, and water thermostat 80.

Main lines 71 and 72 extend from the supply circuit A into the starting and load protective circuits B and C, these two sections being mutually dependent for operation. Starting circuit B is based on a pilot contactor relay 81 which on energization is adapted to close its switches 82 and 83. In addition to the basic elements mentioned the starting circuit includes the hood switches 84 and 85, pilot lamp 86 and main contactor relay switch 87, the circuit passing from main line 72 through tap line 5, pilot lamp 86 and relay 81 in parallel, main relay switch 87, pilot lamp relay contact 83 and hood switch 84 in parallel, and hood switch 85 to the load safety section C. Also from hood and pilot relay switches 83 and 84 a branch line leads through pilot relay switch 82 to a sequence or distributor switch 88, which selects the particular furnace of a bank of furnaces for energization, and thence to the timer circuit section D.

The basic elements of the load-safety section C are the anti-reset relay 89 and switch contact elements 37a, 37b, and 61a, 61b. Anti-reset relay 89 is adapted on energization to open the normally closed anti-reset relay switches 91 and 92.

In addition to the enumerated basic elements there is included in the C section the anti-reset pilot lamp 96, and water temperature and flow switches 100 and 101. The circuit leads from main line 71 through water temperature and flow switches 100 and 101, load switch contact elements 37a and 61a in parallel, through anti-reset relay contact 92, junction point 104, to hood switch 85 of the B section. Also from main line 72 the circuit leads through the anti-reset relay coil 89 and pilot lamp 96 in parallel to a common junction 102; thence by anti-reset relay switch 91 to a common junction 103. From point 103 the circuit leads through switch contact elements 61b and 37b to point 102.

The timer current section D is formed principally of two timers of any appropriate commercial make together with related elements. The function of the timer is to effect a time limit, subject to adjustment, on the amount of heat received by the workpiece and two timers are used to insure completion of a heating cycle in case one timer should fail to perform properly. Timer 110 includes the timer solenoid 111, motor 112 and magnetic timer lock switch 113. Associated with this timer are the timer on-relay 114 and timer on-relay switch 115. A switch for the motor 112 and the relay 114 includes a contact arm 116 which is movable to an "on" contact element 117 and to an "off" contact element 118. Similarly in timer 120 is included the solenoid 121, motor 122, and magnetic lock switch 123. Associated with this timer 120 are timer on-relay 124, timer on-relay switch 125, and contact arm 126 movable to "on" contact element 127 and "off" contact element 128. The timer section D also

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includes the hood solenoid 129 for operating the hood latch, and hood pilot lamp 130 for indicating completion of the heating cycle.

The timer circuit is traced from the sequence selector switch 88 through parallel lines 131 and 132, including timer solenoids 111 and 121 respectively, to the main line 72. To maintain power after opening of sequence switch 88, tap lines are connected at points 133 and 134 on lines 131 and 132 respectively at points between the sequence switch 88 and solenoid coils 111 and 121 respectively, these tap lines leading through the timer switches 113 and 123 respectively and a common return line 135 to point 104 between B and C sections. Line 135 also supplies power to the timer switch arms 116 and 126. The timer on-relay coils 114 and 124 are connected to the main line 72 from points intermediate the "on" timer contact elements 117 and 127 and the corresponding motor. The hood solenoid connects the main line 72 to the "off" timer contact elements 118 and 128.

Associated with timer section D is the main contactor relay 141 with the heat-on pilot lamp 142 connected in parallel therewith. Circuit connections with the timer section are made by extension of timer circuit 135 from tap point 137 through load switch 40, furnace panel door switches 139 associated with various side or rear panel doors, on-relay timer switches 125 and 115 to tap point 140 at the relay 141. Also the main line 72 is extended from tap point 143 through tap point 136 and hood switch 144 (in the switch box 16) to the main contactor relay 141. A pilot lamp 145, indicating complete insertion of the workpiece, connects the power side of the panel door switches 139 with the main line 72.

There remains to be described the high-frequency section E. This section includes the main contactors relay contacts and a rectifying circuit for supplying direct current for operation of the high frequency contactor operating coil. There are two main contactor relay switches 150, 151 and the previously mentioned switch 87 in the starter section B, also operated by the contactor relay.

The rectifying means is embodied as a conventional bridge 152 comprising four branches 153, 154, 155 and 156 with copper oxide or equivalent elements inserted, one in each branch, with such polarity as to produce a direct current potential at tap points 157 and 158, as indicated. Alternating current is led to tap points 159 and 160 on the rectifier from main line 72 at tap point 136 and from the C-D line 135 at a tap point 161, the resultant tap line including in series a resistance cut-in combination of a resistance 162 and normally closed by-pass switch 163 on the resistance, and the main contactor relay switch 151. The rectified circuit connects in series the main contactor relay switch 150 and the high frequency contactor operating coil 164. Energization of magnet coil 164 closes the switch 165 of the high frequency high voltage circuit 166 including the power source 167, capacitor 168 (corresponding to 12 previously mentioned) and heating coil 18. Usually the power source provides current at about 800 volts and 3000 cycles in the heating circuit.

Having in mind the complete organization with associated electrical and mechanical features, the operation of the furnace control follows. The side and rear panel doors are closed closing panel door switches 139. The water cooling system is turned on, this resulting in closure of pressure

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switch 77 and flow switch 101. The main switches 75 are then closed, current flow being indicated by the various current flow indicating lamps 76, 78 and 96. Illumination of lamp 96 indicates a closed circuit through anti-reset relay 89, by way of normally closed load switch contact elements 61b and 37b. Simultaneously, anti-reset relay switches 91 and 92 are closed thus locking the anti-reset relay closed and conditioning the circuits for application of voltage on the starter section B and timer section D on introduction of the workpiece.

The workpiece is now inserted in the furnace chamber causing the closure of load switch contact element 61b and thereby applying voltage to point 104 and starter section B and timer section D.

Before the workpiece has passed completely over load switch arm roller 63, it engages the ejector rod 30, thus actuating the arm of load switch 37. This switch has two contact elements 37a and 37b which are simultaneously actuated, switch contact element 37a serving on closure, to maintain a voltage on the starting and timing circuits irrespective of the action of load switch 61. Opening of either or both 37b or 61a shifts the anti-reset relay circuit entirely through anti-reset relay switch 91 so that should the power be withdrawn from this relay permitting opening of the switch 91, it cannot again be closed unless both load switch contacts 37b and 61a are closed, this requiring complete unloading of the furnace.

The workpiece is now moved to the rear end of the furnace chamber closing load switch 40 in the timer D section. The furnace hood is then closed bringing about closure of hood switches 85 and 144, and a momentary closure of hood switch 84. On the closure of hood switches 85 and 84, a closed circuit is at once established through normally closed main contactor relay switch 87 and the pilot contactor relay 81 with its associated lamp 86. Thereupon the two pilot contactor relay switches 82 and 83 are closed, switch 83 locking the pilot relay 81 closed since hood switch 84 is closed only momentarily during the hood closing movement. Also power is applied by way of switch 82 to the sequence switch 88.

The system of circuits is now conditioned for initiation of a heating cycle. This will develop when the sequence switch 88 which controls the sequence of power application in the furnace bank establishes a closed circuit, to the timer section D. When this occurs timer solenoids 111 and 121 are energized, locking switches 113 and 123 are closed, timer arms 116 and 126 move to on-position at 117 and 127 and motors 112 and 122 function to start the timing cycle. Simultaneously on-position relays 114 and 124 are energized, closing on-relay switches 115 and 125, and since load switch 40, door switches 139 and hood switch 144 are already closed, power is at once supplied from circuit point 104 between sections B and C through line 135, and from main line 72 to the main contactor relay 141 and its associated signal lamp 142.

The energization of relay 141 closes main contactor control relay switches 150 and 151, and opens switch 87 in the starting section circuit. The effect of opening switch 87 is to deenergize pilot contactor coil 81 and cause the opening of pilot contactor relay switches 82 and 83, thus breaking the circuit through the sequence switch. Additionally, closure of main contactor relay switch 151 closes a circuit from point 161 on power

line 135 through the resistance cut-in switch 163 to point 159 on the rectifier bridge 152, thus, applying a voltage at point 160 from main line 72, creating a direct current voltage at points 157 and 158 which is effective through closed switch 150 to energize the high-frequency contactor coil 164. Thereupon, the switch 165 in the main induction heating coil circuit are closed and power from the source 167 is applied to heating coil 18.

On completion of the heating cycle either timer contact arm breaks contact at 117 or 127 and opens relay switches 115 or 125, thus disconnecting relay 141 and opening the main circuit and stopping the application of power. In addition, timer contact arms 116 and 126 engage contact elements 118 and 128 causing functioning of hood solenoid 129 to open the furnace door and hood switches 85 and 144. The workpiece may now be removed from the furnace by actuation of foot pedal 41 and application of tongs.

An outstanding feature of the described system has already been referred to, namely, the impossibility of reconstituting the heating cycle, on interruption of the cycle due to limit switch operation because of drop in cooling water pressure or temperature or control power failure. Should any one of these conditions develop, and the workpiece remain in the furnace, the anti-reset relay coil 89 would be de-energized thus holding switch 92 open and preventing the re-application of voltage on the timer section. In order, therefore, to continue furnace operation it is necessary to remove the billet, bar or other workpiece completely from the furnace in order to reset the anti-reset relay. It is then obvious to the operator that the workpiece has already been fully or partially heated and thus the likelihood of reheating of partially heated bars to the fusion point with resulting damage to the furnace and loss of time and material is avoided.

On normal operation it is impossible to recycle the equipment without completely removing the workpiece from the furnace because it is necessary to remove control voltage from the timers to reset them and this can only be done by opening both load switch contact elements 37a and 51b which due to their mechanical arrangement require the complete removal of the workpiece.

It is observed further that in the described control it is necessary to move the bar or other workpiece completely within the furnace to the rear end thereof before the heating cycle can commence. This is due to the necessity of closing load switch 40 before heating power can flow. Additionally it is pointed out that the hood switch 144, movable to closed position only on lowering of the hood 17, prevents the main contactor relay from functioning when the hood is open and also automatically break the main contactor relay circuit when the hood is opened.

In operation the described system and apparatus work effectively and positively accomplishing diversified results with a relatively simplified arrangement. Obviously, some modification may be made in the details of the system and structure, and hence the scope of the invention should be read from the appended claims.

What is claimed is:

1. In electrical heating apparatus, a heating coil adapted to receive and heat a workpiece, switch means for inducing a heating cycle in said coil on insertion of said workpiece, and means for preventing a renewed heating cycle in said coil after failure and re-establishment of power and prior to complete removal of said workpiece from

the coil, said means including a workpiece operated switch mechanism in operative relation with said coil at each end thereof.

2. In electrical heating apparatus, a heating coil adapted to receive and heat a workpiece, switch means for inducing a heating cycle in said coil on insertion of said workpiece, and means for preventing a renewed heating cycle in said coil after failure and re-establishment of power and prior to complete removal of said workpiece from the coil, said means including at least two switches, and plural means actuated by the workpiece for operating said switches, one of said switch actuating means being adjacent the coil end.

3. An induction heating coil having a hollow heating chamber substantially closed at one end, and adapted to receive a load, plural switches, load operated switch means adjacent the open end of said chamber adapted to operate one of said switches, and load operated switch means intermediate the chamber ends adapted to operate another of said switches, a control circuit connected to said switches for energizing said heating coil, and relay means connected in parallel with said switches effective to prevent re-energizing of said heating coil after an initial heating period and prior to complete removal of the load from said switch means.

4. In electrical heating apparatus, a heating coil adapted to receive and heat a load, power mains, switch means connected to said mains for opening and closing the circuit of said coil, timer means connected to said switch means for timing the heating cycle, a starting control means connected to the timer means and load safety means connected to the starting control means for preventing re-heating of said load, without complete removal of the load from said coil, said load safety means including a switch operated by the movement of the load into and out of said coil.

5. In electrical heating apparatus, a heating coil adapted to receive and heat a load, power mains, switch means connected to said power mains for opening and closing the circuit of said coil, timer means connected to said switch means for timing the heating cycle, a starting control means connected to said timer means, and load safety means connected to said starting control means for preventing re-heating of said load, without complete removal of the load from said coil, said load safety means including plural switches connected across said means and switch operating means positioned at each end of said coil and adapted for separate operation at entry and full insertion of the load within said coil to prevent re-heating of the load prior to complete removal thereof.

6. In electrical heating apparatus, a heating coil adapted to receive and heat a load, switch means for opening and closing the circuit of said coil, power mains, timer means for timing the heating cycle, a starting control means, and load safety means for preventing re-heating of said load, without complete removal of the load from the said coil, said load safety means comprising a relay coil and a relay contact normally open when the relay coil is deenergized connected in series across said mains, load switches connected in parallel with said relay contact and normally closed on removal of load from said heating coil, and additional load switches normally open on removal of load from said heating coil operatively connected to said closed switches and electrically connected to one of said power mains,

for closure or opening of said closed switches, said relay contact being adapted for closure on the energization of the relay coil, and said closed switches to open and open switches to close on the insertion of load within said heating coil, the closing of said open switches by the load, conditioning the timer means for closure of the heating coil circuit.

7. In electrical heating apparatus a heating coil for heating a workpiece, and load safety control means for requiring complete removal of the workpiece after a partial or complete heat treatment thereof prior to additional heating, said means comprising power mains, a relay and relay contacts in series across said mains, load operated switches connected in parallel with said contacts and normally closed on removal of load from the heating coil, and load operated switches normally open on removal of load from said heating coil in series parallel in the power main connected directly to said relay contact, and means placed adjacent the open end of said heating coil for operating one each of said closed and open switches.

8. In electrical heating apparatus, a heating coil for heating a workpiece, and load safety control means for requiring complete removal of the workpiece after a partial or complete heat treatment thereof prior to additional heating, said means comprising power mains, two switches

normally open on removal of a workpiece from said heating coil connected in parallel in one of said power mains, a relay coil and relay contact normally open on disconnection of power from said relay connected in series across said mains, said contact being in the power main including said open switches and in series therewith, two switches normally closed when said heating coil is free of load connected in parallel around said contact whereby on application of power, the relay coil is energized to close and lock said contact, and load operated means effective at one end, and at a point intermediate the ends of the heating coil to close one of said open switches and open one of said closed switches, whereby on opening of the contacts power cannot be re-established in said relay coil prior to complete removal of said load.

9. In electrical heating apparatus, a heating coil adapted to receive a workpiece, switch mechanism for establishing current flow in said coil on insertion of a workpiece therein, and means for preventing a renewal of current flow in said coil after cessation of current flow therein and prior to removal of said workpiece from the coil, said means including a workpiece operable switch in operative relation to said coil at the point adjacent that of full workpiece insertion.

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