June 22, 1954 H. A. STRICKLAND, JR., ET AL 2,681,971

ELECTRIC FURNACE AND CONTROL THEREFOR

Original Filed Jan. 16, 1948 7 Sheets-Sheet 1

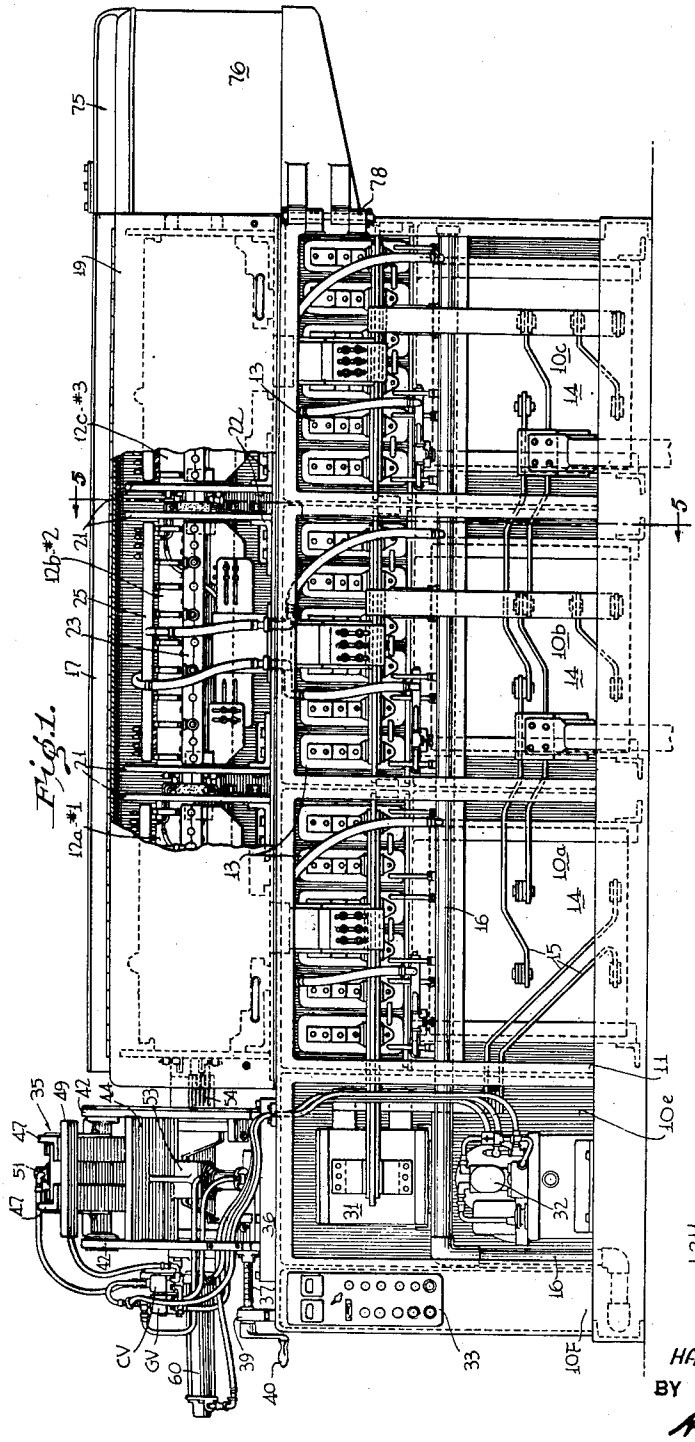


Fig. 1.

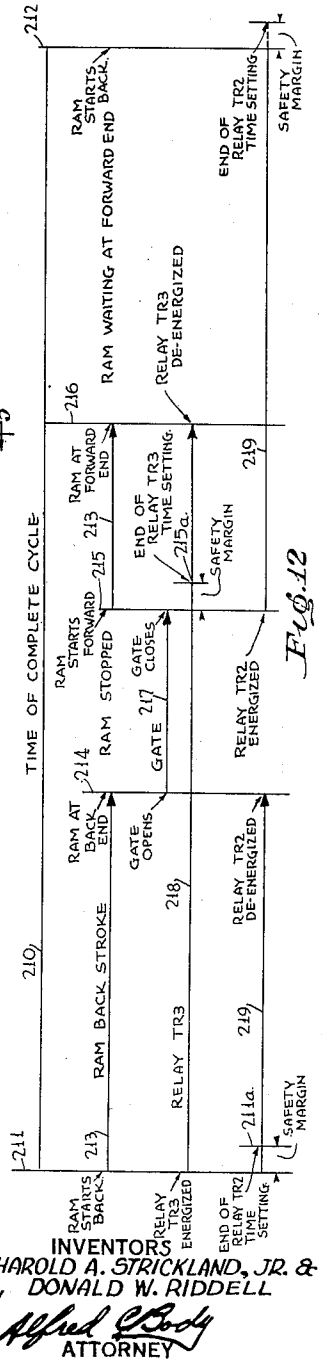


Fig. 12

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ELECTRIC FURNACE AND CONTROL THEREFOR

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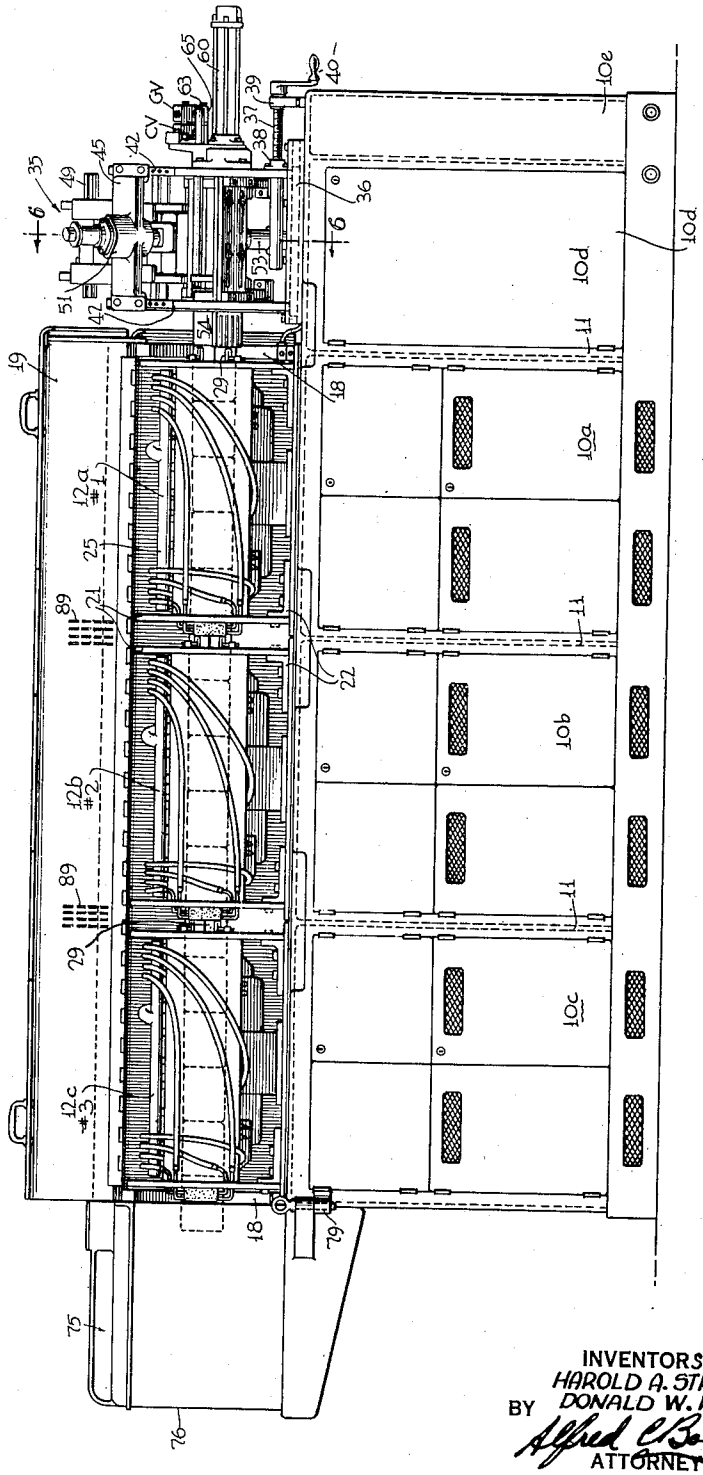


Fig. 2.

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ELECTRIC FURNACE AND CONTROL THEREFOR

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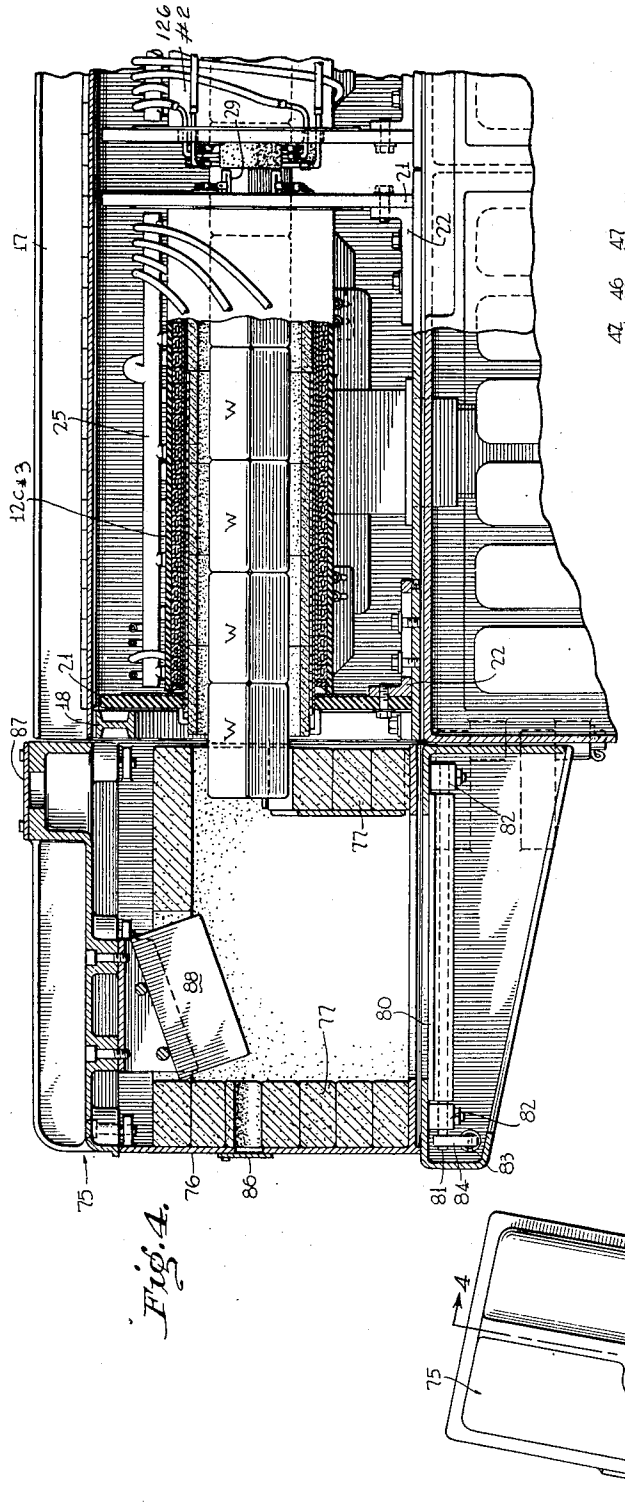


Fig. 4.

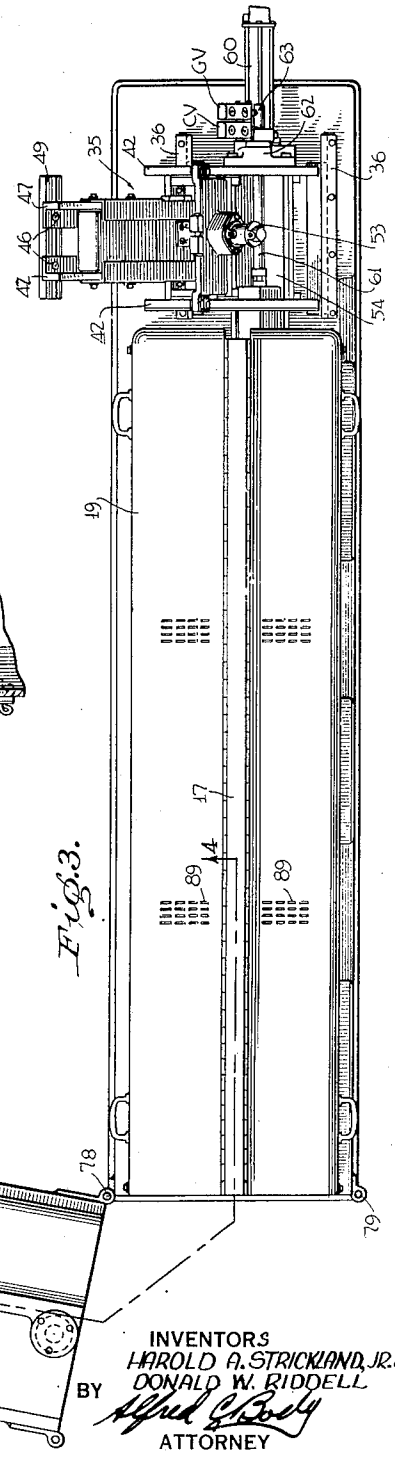


Fig. 3.

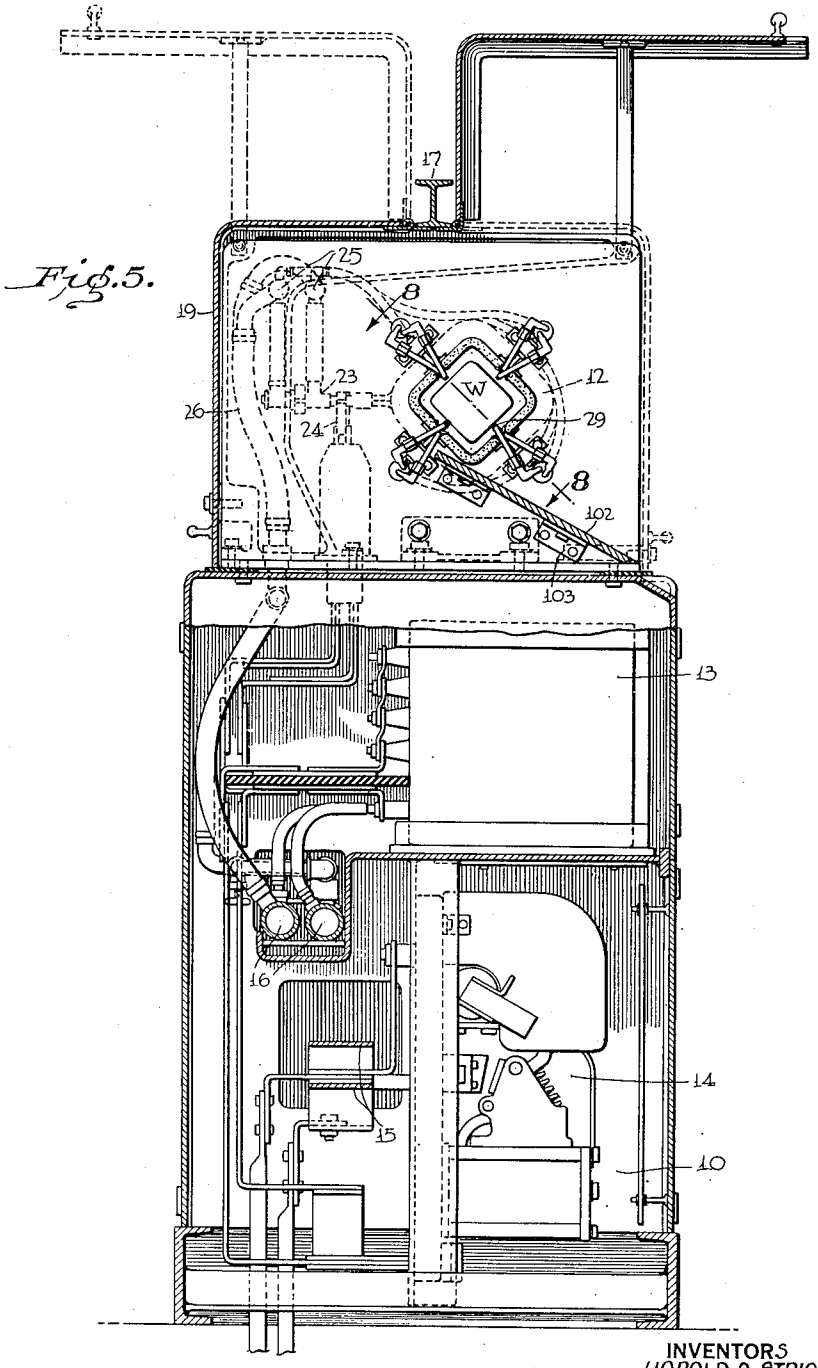
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Fig. 5.



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Fig. 6.

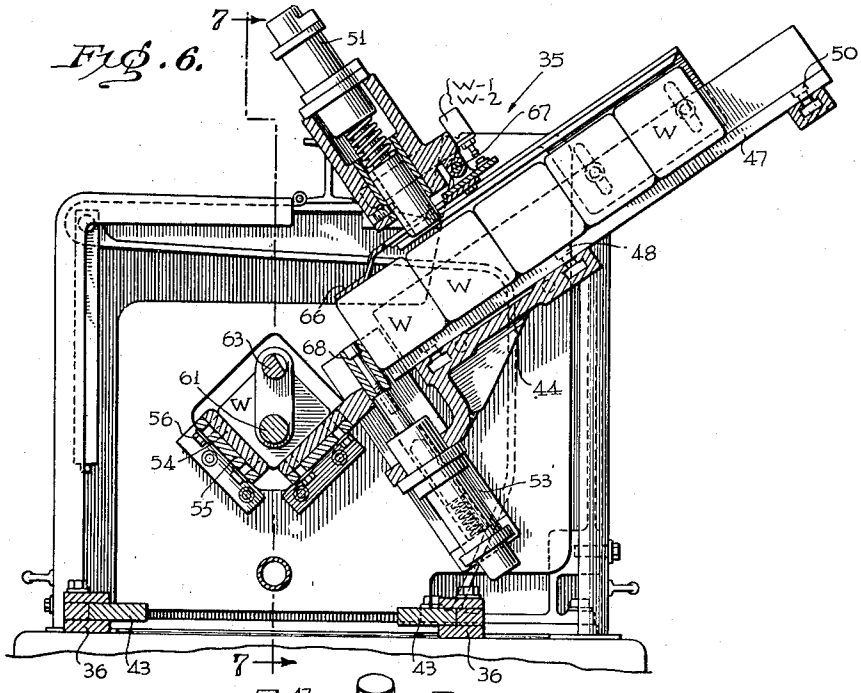
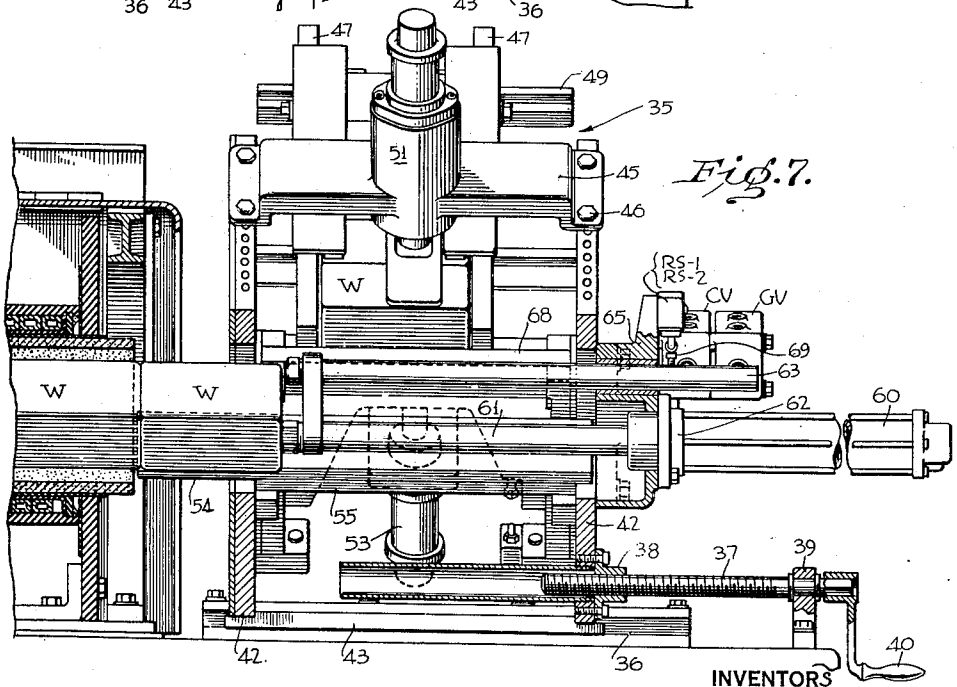


Fig. 7.



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ELECTRIC FURNACE AND CONTROL THEREFOR

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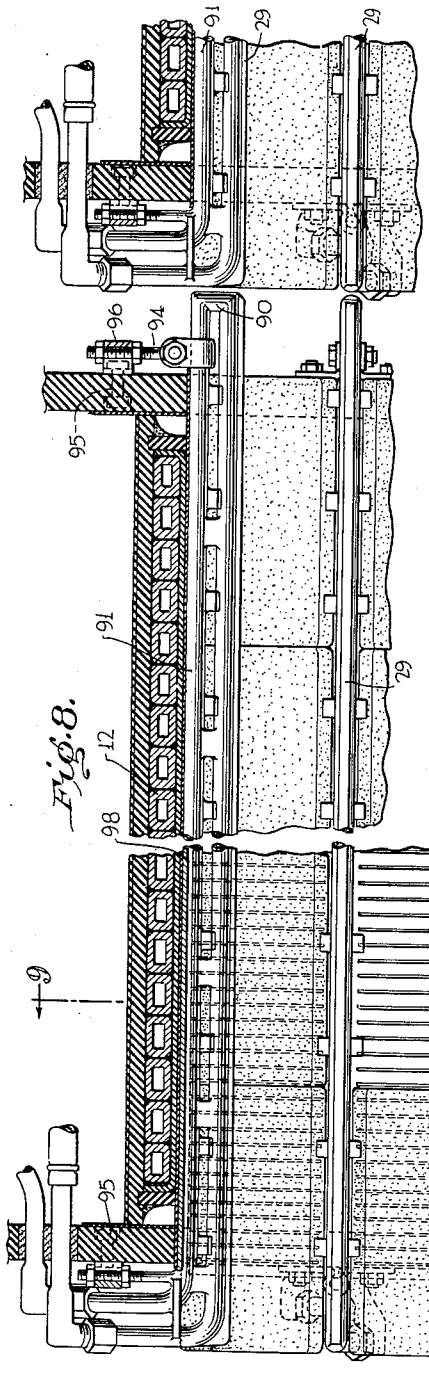


Fig. 8.

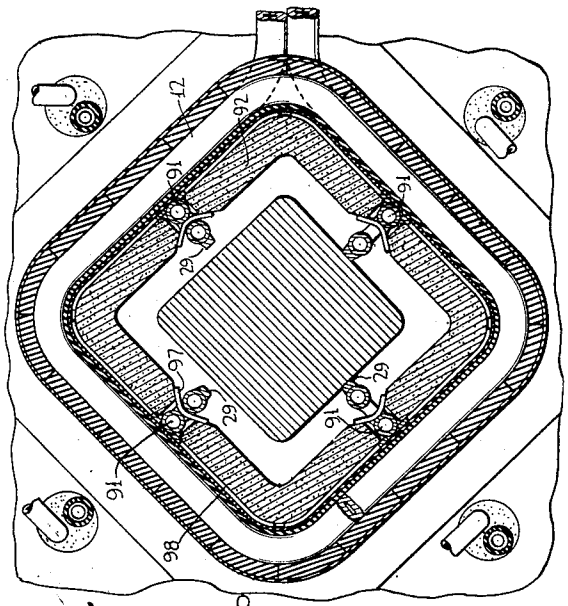


Fig. 9.

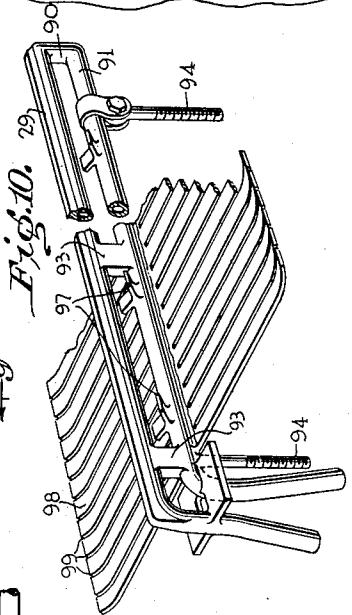


Fig. 10.

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ELECTRIC FURNACE AND CONTROL THEREFOR

Original Filed Jan. 16, 1948 7 Sheets-Sheet 7

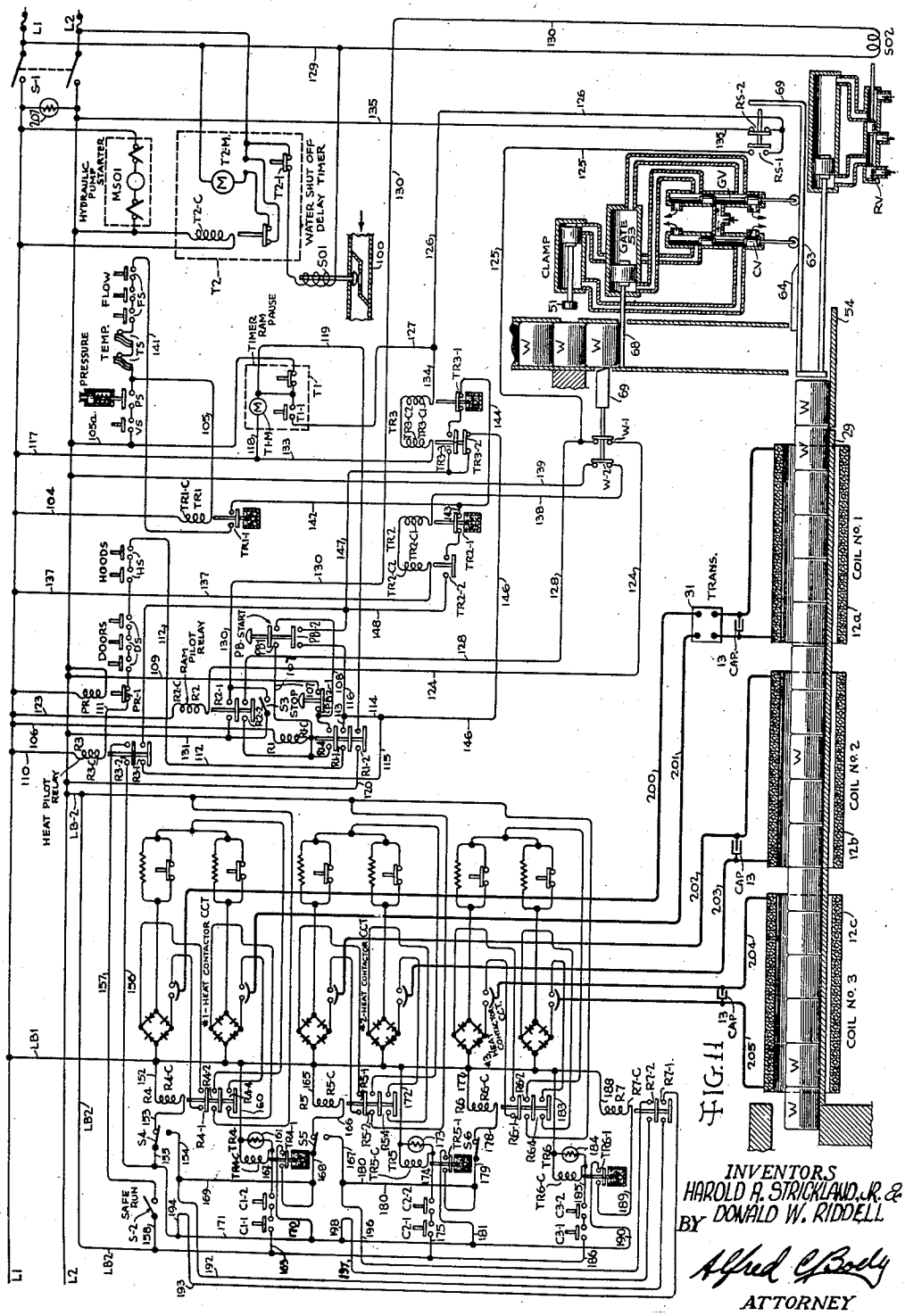


FIG. 11

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Patented June 22, 1954

2,681,971

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2,681,971

ELECTRIC FURNACE AND CONTROL THEREFOR

Harold A. Strickland, Jr., and Donald W. Riddell, Detroit, Mich., assignors, by mesne assignments, to The Ohio Crankshaft Company, Cleveland, Ohio, a corporation of Ohio

Original application January 16, 1948, Serial No. 2,615, now Patent No. 2,572,073, dated October 23, 1951. Divided and this application December 14, 1950, Serial No. 202,616

2 Claims. (Cl. 219—13)

1

This invention relates to heating furnaces, particularly to through feed, or continuous heating furnaces of the high-frequency, induction-heating type disclosed in the patent to Strickland 2,325,638 of August 3, 1943, and has for an object a provision of improvements in this art. This application is a division of our copending application Serial No. 2,615, filed January 16, 1948, now Patent No. 2,572,073, dated October 23, 1951.

One of the particular objects of the invention is to maintain the flow of cooling fluid to the heating coils for a predetermined time after the current has been cut off in order to avoid overheating by hot billets which still remain in the furnace.

Herein, there will be described certain stock-feeding details, coil hoods, soaking-chamber hood, heat shields for the coils, certain time-sequence controls of general application, and various other details which form the subject matter of applications of one or the other of the present co-inventors; namely, application Serial No. 790,154, filed December 6, 1947, now Patent No. 2,604,577, dated July 22, 1952, on an invention entitled "Heating and Work-Handling Apparatus" by the present inventors; application Serial No. 2,613, filed January 16, 1948, now Patent No. 2,563,883, dated August 19, 1951, on an invention entitled "Workpiece Support and Guide for Induction-Heating Furnaces," the inventor there being Harold A. Strickland, Jr., as the sole inventor; and Serial No. 2,614, filed January 16, 1948, now Patent No. 2,578,760, dated December 18, 1951, on an invention entitled "Electric Furnace and Stock-Feeding Means Therefor," the inventor there being Harold A. Strickland, Jr., as the sole inventor.

The above and other objects and advantages of the invention will be apparent from the following description of an exemplary embodiment of the invention, reference being made to the accompanying drawings thereof, wherein:

Figure 1 is a right-side elevation, with some of the cover panels or doors removed and part of the coil hood cut away, of a three-coil furnace and related feeding apparatus embodying the present invention;

Figure 2 is a left-side elevation of the same apparatus with the doors in place and with the hood in raised position;

Figure 3 is a top plan view with the hoods closed and with the soaking-chamber hood swung out to one side;

Figure 4 is an enlarged partial vertical section of the rear or discharge end of the furnace, the

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section being taken on the line 4—4 of Figure 3 but with the soaking-chamber hood returned to its normal operating position;

Figure 5 is a transverse vertical section and elevation taken on the line 5—5 of Figure 1;

Figure 6 is a partial vertical transverse section taken on the line 6—6 of Figure 2;

Figure 7 is a left-side elevation and section taken on the line 7—7 of Figure 6;

Figure 8 is an inclined longitudinal section and elevation taken about on the line 8—8 of Figure 5;

Figure 9 is a transverse vertical section taken on the line 9—9 of Figure 8;

Figure 10 is a perspective view of the cooled stock guide rails and related parts;

Figure 11 is a schematic view and wiring diagram; and

Figure 12 is a cycle diagram.

The furnace herein shown comprises a supporting frame or multiple-unit cabinet 10 with three units 10_a, 10_b and 10_c associated with a skeleton framework 11 which is welded or riveted up from angle, channel or other standard pieces of metal as needed for the number of heating units to be used. Mounted above and in association respectively with each of the cabinets are a like number of electric induction-heating coils 12, here distinguished as 12_a, 12_b and 12_c. From front to rear end, or right to left in Figure 2, these heating coils are also referred to as No. 1, No. 2 and No. 3. Preferably, high-frequency heating current is used for heating.

In the upper part of each cabinet, there are placed a number of capacitors 13 and, in the lower part of each cabinet, there are placed suitable contactors 14. There are two contactors for each coil and one of these is shown in side elevation in Figure 5.

Suitable bus bars and connections, all indicated generally by the numeral 15, are shown for serving the contactors, capacitors and coils. Common cooling fluid conduits 16 are provided for the several coils.

A beam 17, here of I-section, extends above the entire furnace; that is, above all of the coils in whatever number provided, the beam being supported at its ends by end supports 18. At each side of the beam 17, there is hinged one or more coil-hood members 19 which may be closed, as shown in Figure 1, or opened, as shown in Figure 2.

Aside from the main frame 11, the bus bars 15, the beam 17 and the hoods 19, the apparatus has no parts which extend between units except con-

trol circuit wiring, and the self-contained and identical heating units comprising coil, capacitors, contactors and related parts may be readily assembled in any desired number.

In each unit, the coil 12 is mounted as a removable unit on insulating end-support plates 21 which are detachably secured to bottom brackets 22 secured on the frame 11. Each coil unit carries with it a bus assembly 23 which is detachably secured to fixed adjustable bus connections 24, and each unit also carries cooling-fluid manifolds 25 which are disconnectible at hose connections 26 leading to the long fluid conduits 16.

As shown in Figures 4, 8, 9 and 10, each heating coil is provided with stock-supporting and guide rails 29 which project out of each end to such distance that, in the open space between coils, the rails are very close together to form, in effect, continuous surfaces over which the work may move. However, the rails of adjacent coils can move laterally relative to each other so as not to interfere with the movement of a coil when being removed or replaced. The details of the guide rails and associated parts will be described later. In this particular, the present application is a continuation in part of the application of Harold A. Strickland, Jr., Serial No. 681,996, filed July 8, 1946, now Patent No. 2,541,123, dated February 13, 1951.

At the front end of the furnace, another cabinet 10_d is provided to house apparatus of a general nature which serves all coils in common, the apparatus here shown, Figure 1, comprising transformers 31 and operating pressure fluid pumping and controlling apparatus 32.

The extreme front cabinet 10_e houses the timers, switchboard, switches, relays, and other control apparatus. Some of the controls are mounted on a panel 33 on the side at the front where they will be accessible to an operator when in his usual position for feeding workpieces or billets to the machine.

The cabinets 10_d and 10_e and their equipment are provided for all furnaces, whether assembled as one-coil heaters or as multi-coil heaters.

Mounted upon the top of the cabinets 10_d and 10_e is a work-feed unit 35 which is movable axially of the furnace upon guides 36 and is adjusted as a unit by a screw 37 threaded into a sleeve 38 mounted on the feed unit. The screw is rotatable but held against endwise movement in a support bearing 39 and is turned by a crank 40.

The feed mechanism comprises spaced end supports 42 which are permanently secured at a fixed distance apart on a base 43 which slides on the guides 36. The end supports are further held in fixed spaced relation by an inclined chute support piece 44 and an upper cross bar 45 which is held in vertically adjusted positions on the end supports by set screws 46. Chute guides 47 are adjustably secured to the support piece 44 by set screws 48 to provide for billets or workpieces W of different lengths. At the upper end, the chute guides are further held in adjusted positions by a slotted piece 49 and set screws 50. The upper cross bar 45 carries a clamp device 51 for clamping billets in the chute and the vertical adjustment of the cross bar accommodates for billets of different thicknesses.

The support piece 44 has mounted thereon a gate device 53 which controls the down feed of billets to loading position. Both the clamp device 51 and the gate device 53 are here formed as cylinder-piston devices operated by pressure fluid.

From the chute, a billet, when released by the opening of the gate 53, falls upon a V-shaped feed trough 54 which is adjustably held on a cross piece 55 by bolts 56 so as to be adjustable endwise to stand close to the projecting rails of the #1 coil. When the feed device is adjusted, the trough is readjusted to bring it near the furnace rails. The V-trough plates are slotted from their ends to avoid inductance from the furnace coil.

A pusher device 60, comprising piston and cylinder parts and a ram 61, is mounted on the outer end plate 42, as by a ring 62. On one side the ram carries a valve cam bar 63 having a cam 64 for operating the stems of a clamp valve CV and a gate valve GV respectively. The valve devices are mounted on a support bracket 65 carried by an end plate 42.

A switch plate 66, hinged at 67 (Figure 6), has its lower end located where it will be raised by a billet in the lowermost position just above the gate plate 68. The upper end of the switch plate, when raised by the dropping of the lower end, operates micro-switches W–1, W–2, later to be described.

The valve cam bar 63, when the piston is at the forward end of its stroke, operates a switch actuator 69 for switches RS–1 and RS–2 which will be described later.

The exit or delivery end of the furnace beyond the rear end of the last heating coil has means for supporting a workpiece for a pause period to allow heat to penetrate toward the center. The coils heat so rapidly on the outside by induction that this soaking time is useful in preparing the workpiece for forging. As a matter of fact, the spaces between adjacent coils also provide a soaking time. It is to be understood that the current characteristics will be chosen so as to best serve the conditions imposed; for example, a single coil furnace heating more deeply than a multi-coil furnace, but there is usually some need for a soaking time.

Surrounding the furnace exit and covering what may be termed a soaking chamber, there is provided a heat-insulated hood 75 which comprises a metal casing 76 and a heat-insulating lining 77. The hood is supported for swinging movement on a vertical axis on one side of the furnace by hinges 78 and is held in closed position by a latch pin 79 on the other side.

At the bottom, the hood is provided with swinging doors 80, which may be referred to as "bomb bay" doors, these being mounted on hinge shafts 81 in bearing brackets 82 and being urged to closed position, as by a spring 83 secured between arms 84 carried by the door shafts 81. When a workpiece is pushed out from the soaking chamber, it drops upon the doors to open them and pass through them, whereupon the spring 83 causes the doors to close again. At the end of the furnace and in line with its chamber axis, the hood 75 is provided with a transparency-covered sight opening 86. Another sight opening 87 is provided in the top of the hood. A billet deflector 88 is provided in the top of the hood to cause an end billet to break away from the next billet in case they may be slightly fused together. At the sight opening 87 or at some other location in the hood, a heat or light-responsive device, which may be referred to as an electric eye or photo relay, is provided to control the temperature of the emerging billets; more particularly, to shut off the heat if billets are

near the melting point to endanger the heating coils. This device is indicated only in the wiring diagram where it is designated as PR.

In the coil hoods 19, there are provided vent openings 89 above the open space between coils to release heat, gases or smoke from the billets resting in the space between coils. It will be noted from Figures 4, 8, 9 and 10, that the guide rails 29 are tubular and are cooled by fluid from disconnectible feed and return lines at one end. The cooling tubes are returned outwardly as at 90 at one end and have an outer run 91 which is located within the confines of the coil-insulating lining 92 to keep it and the heating coil cool. The double-rail construction with interconnecting supports 93 also provides strength for holding the insulation in place. The cooling rails are mounted on the coil-end plates 21 by bolts 94, 95 and adjustable connectors 96. It will be noted that the line-connected ends of the rails are returned through a coil support plate 21 and have their line connections above the outside of the coil and between its supporting plates, where there will be protection from heat. The inner run of the cooling rail is coated with a wear-resisting liner fused thereon. There are a number of suitable materials, one such being a composition of tungsten 12–17%, chromium, 30–35%, carbon 2.25–2.75%, cobalt, substantially the balance, this being known commercially as "Stellite." The outer run 91 is provided with wings 97 which are fused thereon to hold the heat-insulating lining of the coil.

For such coils or portions of coils as are subject to unusual heat from billets after they have been heated to high temperature, there is provided a special heat-dissipating means; for example, of the type shown in Figures 8, 9 and 10. Here, an extensive area of a highly heat-conductive material, such as copper, is soldered to the outer run 91 of the rails so as to lie outside the heat insulation and inside the coil lining. The fins or plates 98 thus provided are slitted as at 99 to avoid buckling or other objectionable features of continuous sheets for such a use. It is found that if the heat shields are coextensive with the last approximately one fifth of the total heating coil length, they will provide adequate coil protection and prolong coil life to a remarkable degree.

Between the ends of adjacent coils, inclined plates 102 may be provided for directing scale and dirt toward the outside of the cabinet assembly, the plates being supported upon brackets 103 on the coil-end plates 21.

The operation of the apparatus will be described in connection with the circuit diagram, Figure 11.

The ram 61 normally stops in its forward position; that is, toward the rear end of the machine as a whole. It is shown slightly back of forward position to illustrate its switches RS–1 and RS–2 in their nonoperated position. In the normal full forward stopped position of the ram, its switch RS–1 is closed and its switch RS–2 is open. RS–1 opens and RS–2 closes as soon as the ram starts to move back.

A ram pause timer T1 causes the ram to rest at the front end of its stroke. It is settable for a wide range of time merely by moving a fixed contact hand which is engaged after the predetermined time lapse by a movable hand driven by a synchronous motor. This represents one form of timer which may be used. The end of the preset timer period is registered by closure of its switch T1–1. Its motor is represented by the reference character T1–M. By providing the pause timer T1, a number of control advantages are obtained, including the ability to adjust for different feed rates for billets of different size, different coils, different heats desired, and matching of delivery periods to suit the needs of the forging machines which use the billets heated by this machine.

The ram cylinder is provided with a valve RV operated by solenoid SO2. The arrangement is such that when the solenoid SO2 is not energized, the ram stays in its forward position and when the solenoid is energized, the ram returns to its rear position.

The ram cam bar 63, which carries the cam 64 for operating the valves CV and GV for the clamp 51 and gate 53 respectively, is shown also in Figure 11. As the ram approaches the rear end of its travel, the associated valve CV causes the clamp 51 to hold the billet which is in next-to-last position. Later, near the rear end of the ram travel, the associated valve GV causes the gate to be lowered to drop the billet from last position to the V-trough 54. When the ram moves forward again, it first replaces the gate in the chute and later releases the clamp to allow the stack of billets in the chute to slide down against the gate.

When the billet in last position drops, it opens switches W–1 and W–2, and when another billet drops to the last position, it closes these switches. If no billet drops down, the machine is stopped after a certain lapse of time. Whenever TR3 or TR2 becomes deenergized, the auxiliary switches open immediately.

To prepare for the start of operations, the main line switch S–1 of L1, L2 is closed. For heating, as well as ram operation, a switch S–2, which may be referred to as a "safe-run" switch, is closed. For operation of the ram only, S–2 is left open. The cooling water for the coils is turned on. This closes water shut-off valve switch VS, pressure switch PS and flow switches FS to the coils (three here). The temperature at the coils is assumed to be not excessive so temperature switches TS are closed. The panels or doors of the cabinet are closed so their safety switches DS are closed. The hoods are closed so hood-safety switches HS are closed. The ram is to be actuated and not held to a rear position so the "ram-return" switch S–3 is opened.

The clutch coil T2–C of water shut-off delay timer T2 is kept energized as long as S–1 is kept closed. It holds out the timer clutch but when S–1 is opened, the clutch is engaged and after a time-delay period, the timer switch is actuated to actuate solenoid SO1 to shut off water to bypass 106 supplying the heating coils. The synchronous motor for T2 is designated as T2–M.

A time-delay relay TR1 is energized and after a delay to allow bubbles to be removed from the cooling fluid lines, its switch TR1–1 is closed. The circuit involved is: L1, conductor 104, TR1–C, conductor 105, PS, VS, conductor 105*a*, to L2.

The time-delay relays are represented by separate coils for instantaneous and delay-switch operation, and the delay switch is represented as carrying hinged vanes which can fold together and move rapidly in a fluid in one direction of movement but which spread and cause slow movement in the other direction. This is merely symbolic. Delay-action timers which are settable for timed periods of any predetermined length are available on the market.

It will be assumed that the photoelectric relay PR will be used in the soaking chamber to indicate when billets are overheated. Its switch PR–1 is in series with the door and hood-safety switches DS and HS.

To start operations, the start push button PB is pressed to close PB–1 and PB–2.

Closure of PB–1 energizes relay R1 and the relay locks in on its switch R1–4. The circuit completed here is: L1, conductor 106, coil R1–C, conductor 107, PB–1, conductor 108, stop push-button switch PB2–1, conductor 109, to L2. Closure of R1–4 shorts out 107, PB–1 and 108. R1 also closes R1–1 in the line to "heat pilot relay" R3 but this has no effect as yet because the circuit is open elsewhere. The circuit involved is: L1, conductor 110, R3–C, conductor 111, PR–1, DS, HS, conductor 112, R1–1, conductor 113, conductor 114, conductor 115, to R3–1, which is open (or from 113 to conductor 116 and PB–2 which also leads to open points). R1 also closes R1–2 to connect the ram pause timer relay T1 to L2. The circuit involved is: L1, conductor 117, conductor 118, T1–M, conductor 119, R1–2, conductor 120, to L2. The closure of PB–2 has no effect at this time as the circuit is open at both TR2 and TR3.

When the ram is fully at front end of its stroke, its switch RS–1 is closed and RS–2 opened.

RS–1, being closed, timer T1 is set into action and after a timed period, the ram pilot relay R2 is energized. The circuit involved is: L1, conductor 123, R2–C, conductor 124, W–1 (now closed), conductor 125, RS–1, conductor 126, conductor 127, T1–1, 119, R1–2, 120, to L2.

Energization of R2 closes its switch R2–2 which locks it in circuit and only the opening of W–1 or R1–4 will deenergize it. It also closes R2–1 which energizes ram valve solenoid SO2 and supplies fluid to the rod end of the ram cylinder and the ram retracts. The lock circuit is: L1, 123, R2–C, 124, W–1, conductor 128. The circuit involved to energize SO2 is: L1, conductor 129, SO2, conductor 130, R2–1, conductor 131, to L2.

At the same time, timer T1 energizes time-delay relay TR3. The circuit involved is: L1, 117, conductor 133, TR3–C2, TR3–C1, conductor 134, 127, T1–1, 119, R1–2, 120, to L2.

When ram starts to retract, it opens RS–1 and closes RS–2.

Closure of RS–2 puts TR3 directly in circuit where it will stay until RS–2 is again opened when the ram is at the forward end of its stroke again. The short or lock circuit for TR3 is: TR3–C1, 134, 126, RS–2, conductor 135, to L2.

Energization of TR3 opens TR3–2 and closes TR3–3. TR3–1 delays in opening, being timed to open after the ram has returned and the gate has opened and closed.

As the ram approaches the rear end of its stroke, its cam bar causes clamp valve CV to be actuated to clamp a billet in the next-to-last position in the chute. At the rear end of its stroke, it opens the gate to feed down a billet upon the guide.

Dropping down of a billet from the last position opens switches W–1 and W–2.

Opening of W–1 deenergizes R2 and causes the ram to move forward. It should here be noted that when the machine was energized by closing S–1, and assuming a billet to be in the last or feed-down position to keep W–2 closed, a time-delay relay TR2 will at once be energized and will be kept energized as long as W–2 is kept closed. The circuit involved is: L1, conductor 137, TR2–C2, TR2–C1, conductor 138, W–2, conductor 139, to L2. Opening of W–2 deenergizes TR2 and causes it to open TR2–2 and close TR2–1, both without delay.

As the ram moves forward, its cam bar first causes the gate to close the bottom end of the chute and later causes the clamp to release its billet to allow the whole stack to descend. The lowermost billet closes switches W–1 and W–2.

Closure of W–1 has no immediate effect but the closure of W–2 energizes TR2 again.

It will be assumed that the time-delay relay TR1 will have closed its switch TR1–1 completing a line to one side each of TR2–1 and TR3–1. The line established is as follows: L2, 105*a*, VS, PS, TS, FS, conductor 141, TR1–1, conductor 142, 143 to TR2–1, and 144 to TR3–1.

Energization of TR2 closes TR2–2 at once and begins a timing period for TR2–1 to open. It is set to open after the ram has moved forward and paused at the outer end for its preset waiting period.

The closed condition of both switches of TR2 has no immediate effect because TR3 is still energized and TR3–2 is closed and TR3–1 not yet timed out if set properly.

At the end of its forward stroke, the ram closes RS–1 and opens RS–2.

Opening of RS–2 deenergizes TR3 and this closes TR3–1 and TR3–2 and opens TR3–3, all without delay.

Closure of TR3–2 (TR2–2 and TR2–1 being closed) energizes the heat pilot relay R3. The circuit involved is: L1, R3–C, 111, PR–1, DS, HS, 112, R1–1, 113, 114, conductor 146, TR3–2, conductor 147, conductor 148, TR2–2, TR2–1, 143, 142, TR1–1, 141, FS, TS, PS, VS, 105*a*, to L2.

Energization of R3 closes its switch R3–1 to lock in past TR3–2. The circuit involved is: L1, 110, R3–C, 111, PR–1, DS, HS, 112, R1–1, 113, 115, R3–1, conductor 150, 148, TR2–2, TR2–1, 143, 142, TR1–1, etc., to L2. It also closes R3–2 to the contactor relay circuits.

Closure of R3–2 energizes #1 contactor relay R4 which closes the switches R4–1, R4–2 and R4–4 of the #1 contactors and these, when closed, close #1 contactor interlocks C1–1, C1–2. The circuit involved in energizing R4 is: L1, branch conductor LB1, conductor 152, R4–C, conductor 153, switch S–4 (which is here closed on its normal contacts but which may be changed from 153 to an alternate route 154 to a switch R7–1, in brief the shift of S–4 to 154 shorting out R4), conductor 155, conductor 156, R3–2, conductor 157, S–2, conductor 158, LB2, to L2.

Closure of C1–1 and C1–2 energizes TR4 which, after a delay period, closes TR4–1. The circuit involved is: LB1, conductor 160, TR4–C (pilot lamp 161 in parallel), conductor 162, C1–2, C1–1, conductor 163, to LB2.

Closure of TR4–1 energizes #2 contactor relay R5 which, through its switches R5–1, R5–2, R5–4, actuates the #2 contactors and these, when closed, close #2 contactor interlocks C2–1 and C2–2. The circuit involved to energize R5 is: LB1, conductor 165, R5–C, conductor 166, S–5 (closed from 168 to 166 but shiftable when desired to 167 to cut out R5 to 167), conductor 168 (connected by conductor 169 to 154 of S–4), TR4–1, conductor 170, conductor 171, 156, R3–2, 157, S–2, 158, to LB2.

Closure of C2–1 and C2–2 energizes TR5, which, after a delay period, closes TR5–1. The circuit involved is: LB1, conductor 172, TR5–C (pilot

lamp 173 in parallel), conductor 174, C2–2, C2–1, conductor 175, to LB2.

Closure of TR5–1 energizes #3 contactor relay R6 which, through its switches R6–1, R6–2, R6–4, actuates the #3 contactors and these, when closed, close #3 contactor interlocks C3–1 and C3–2. The circuit involved to energize R6 is LB1, conductor 177, R6–C, conductor 178, S–6 (closed to 178 but shiftable to open), conductor 179 (connected by conductor 180 to 167 of S–5), TR5–1, conductor 181, 171, 156, R3–2, 157, S–2, 158, to LB2.

Closure of C3–1 and C3–2 energizes TR6 which, after a delay period, closes TR6–1. The circuit involved is: LB1, conductor 183, TR6–C (pilot lamp 184 in parallel), conductor 185, C3–2, C3–1, conductor 186, to LB2.

Closure of TR6–1 energizes relay R7. The circuit involved is: LB1, conductor 188, R7–C, conductor 189, TR6–1, conductor 190, 171, 156, R3–2, 157, S–2, 158, to LB2.

Heat is thus placed successively on all three heating coils.

If the heat goes off and remains off for less than a predetermined period and R3–2 is closed, this will find the delay switch TR6–1 closed and this will cause R7 to be energized which immediately closes R7–1, R7–2 to supply current to the #2 and #3 coils. R3–2 causes current to be supplied to coil #1 so all coils will be energized at one time. The circuit involved to supply current to the #2 coil is as follows: LB1, 165, R5–C, 166, S–5, 168, 169, 154, conductor 192, R7–1, conductor 193, conductor 194, 171, 156, R3–2, 157, S–2, 158, to LB2; and for current to #3 coil is as follows: LB1, 177, R6–C, 178, S–6, 179, 180, conductor 196, R7–2, conductor 197, conductor 198, 171, 156, R3–2, 157, S–2, 158, to LB2.

At the end of the waiting period, the timer T1 energizes ram-pilot relay R2 to cause the ram to return, as before. It also energizes TR3, as before.

Energization of TR3 closes TR3–3 and leaves TR3–1 closed (until later opened) so heat-pilot relay R3 is held in when TR2–1 shortly opens. If TR2–1 opens first, R3 will be deenergized to open R3–1 so that the latter closure of TR3–3 will be ineffective to keep the heat on. However, operation of PB–2 would restore heat.

Similarly, if TR3–1 opens (as it should shortly after the gate closes) before TR2–2 closes when the gate closes, R3 will be deenergized and closure of TR2–2 (TR3 still being energized and TR3–2 open) will not energize R3. Again, closure of PB–2 would apply heat.

Hence, this allows the operator to put in billets and start the heat again without waiting.

The failure of W–1 to close again after the last billet is fed down would prevent the ram from being returned from the outer end of its stroke.

The insertion of billets in the chute closes W–1 and W–2 and causes the ram to start operating again.

The heat contactor circuits are of known type and it is here only necessary to know that there are two contactors for each coil and that they supply the coils with high-frequency current, derived from an independent source, by way of conductors 200, 201 for coil #1, 202, 203 for coil #2, and 204, 205 for coil #3. Suitable control of multi-coil furnaces may be provided by using a transformer for one coil only; for example, coil #1 as illustrated.

A solenoid MSO1 is provided for starting the hydraulic pump motor when current is turned on at S–1, overload devices OL being provided in connection therewith.

A pilot lamp 207 indicates when the switch S–1 is closed.

The timing of operations will be clearer from consideration of Figure 12, showing the cycle diagram. The duration of one complete cycle is represented by the top horizontal line 210 which extends between the vertical start line 211 and the vertical finish line 212. The second horizontal line 213 represents the ram movements. It starts back at line 211 and completes its backstroke at a vertical line 214. It starts again at the vertical line 215 and completes its forward stroke at the vertical line 216. The ram waits at the forward end of its stroke, as represented by the distance between the lines 216 and 212. The third horizontal line 217 represents the gate operation, which opens approximately at the line 214 to feed down a billet, and closes approximately at the line 215.

The horizontal line 218 represents the action of time-delay relay TR3. It is energized at ordinate 211 and deenergized at the line 216 but its time-delay switch TR3–1 is set for actuation at a point 215*a* which is a short time after the ram is supposed to start forward. Hence, if there is any jam in the ram return or in the billet feed, the heating current will be shut off. If there is no workpiece or billet in the feed-down position to close switches W–1, W–2, the ram also will stop when it reaches the front end of its stroke, assuming that the ram did not jam on its backstroke but merely failed to get back on time.

The line 219 represents the action of time-delay relay TR2. It is energized at the ordinate 215 where the ram starts forward and remains energized until the ram returns. Its switch TR2–1, however, is timed for actuation at the point 211*a* which is slightly after the ram is scheduled to start its return movement. Hence, if there is any jam in the forward movement of the ram or if the proper pause at the front end of the ram stroke has not been observed, the heating current is cut off.

To make the original setting, it is only necessary to place the movable contact element of the relay at a point some distance beyond the point required by the operations to be matched and supervised and then gradually to move the contact back until only a slight margin of safety is left. In this way, the supervisory response may be made as fine or coarse as may be desired.

It is thus seen that the invention provides improved controls for a work-heating furnace, particularly for an induction-heating furnace. The time-delay elements are in part interposed as delay elements in the action of work-feeding devices and in part are matched with the actions of the feeding devices in a supervisory capacity to provide safety in operation in case the feed devices do not function properly. Also, there are provided means for applying current to a plurality of coils consecutively at time intervals or applying current to all of the coils simultaneously in case current has not been off long enough to allow workpieces to cool beyond a desired amount. There are also provided means for selectively cutting any of the coils in or out of action and means for shutting down the furnace in case the emerging workpieces are hotter than desired. Also, means are provided for causing cooling fluid to flow to the coils until they and the load of workpieces have

cooled. There are various improvements in details of construction and operation which provide great rapidity and facility in changing from one type of operation to another.

While one embodiment has been described for purposes of illustration, it is to be understood that there may be various embodiments within the limits of the prior art and the scope of the subjoined claims.

What is claimed is:

1. In a high-frequency induction-heating furnace of the type adapted to have a billet disposed therein to be heated to an elevated temperature, said furnace comprising a multiturn helical coil on the interior of which the billet is positioned, said coil being formed of a hollow tube and having means for flowing a cooling medium through the hollow of such coil and away therefrom and for controlling such flow, means for preventing a supply of electrical power to the coil unless the cooling medium is flowing therethrough, said furnace being of the type subject to damage if a heated workpiece is left in position without cooling medium flowing through said coil, the improvement which comprises timing means associated with a means for controlling the flow of cooling medium through the coil operative upon the failure of electrical power to the coil for any reason to insure the flow of cooling medium through the coil for a time period sufficient to insure that any heated workpieces in the coil will have cooled below a temperature sufficient to cause damage to the coil.

2. In a high-frequency induction-heating furnace of the type adapted to have a billet positioned therein and heated to an elevated temperature, said furnace comprising a multiturn helical coil in which the billets to be heated are positioned, said coil being formed of a hollow tube, means for flowing a cooling medium through said coil and away therefrom and controlling such flow, means for continuously feeding new billets to be heated into said coil and ejecting heated billets therefrom, means associated with said feeding means to deenergize said coil in the event of a failure to properly feed and eject billets, said furnace being of a type subject to damage if a heated billet is left in position within the coil without the cooling medium flowing through the coil, the improvement which comprises timing means automatically operable upon the deenergization of said coil for any purpose and after a time period at least sufficient for billets to cool to a temperature below that at which they can cause damage to said coil for insuring that damage to said coil will not occur upon the failure of operation of the furnace for any reason.

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