Oct. 25, 1949. H. F. STORM 2,485,785

HIGH-FREQUENCY INDUCTION HEATING SYSTEM

Filed June 7, 1944 3 Sheets-Sheet 1

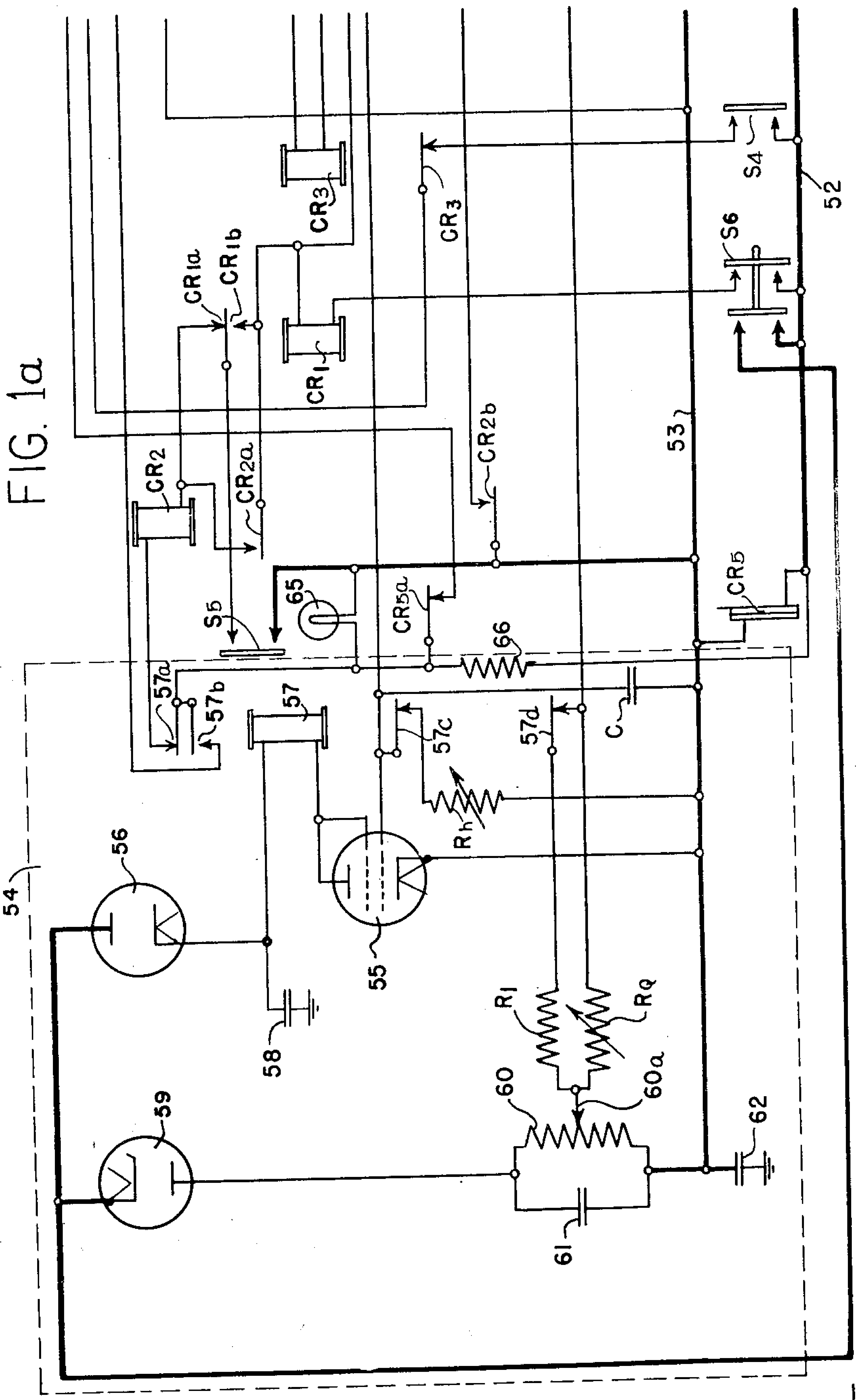

FIG. 1a

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Filed June 7, 1944 3 Sheets-Sheet 2

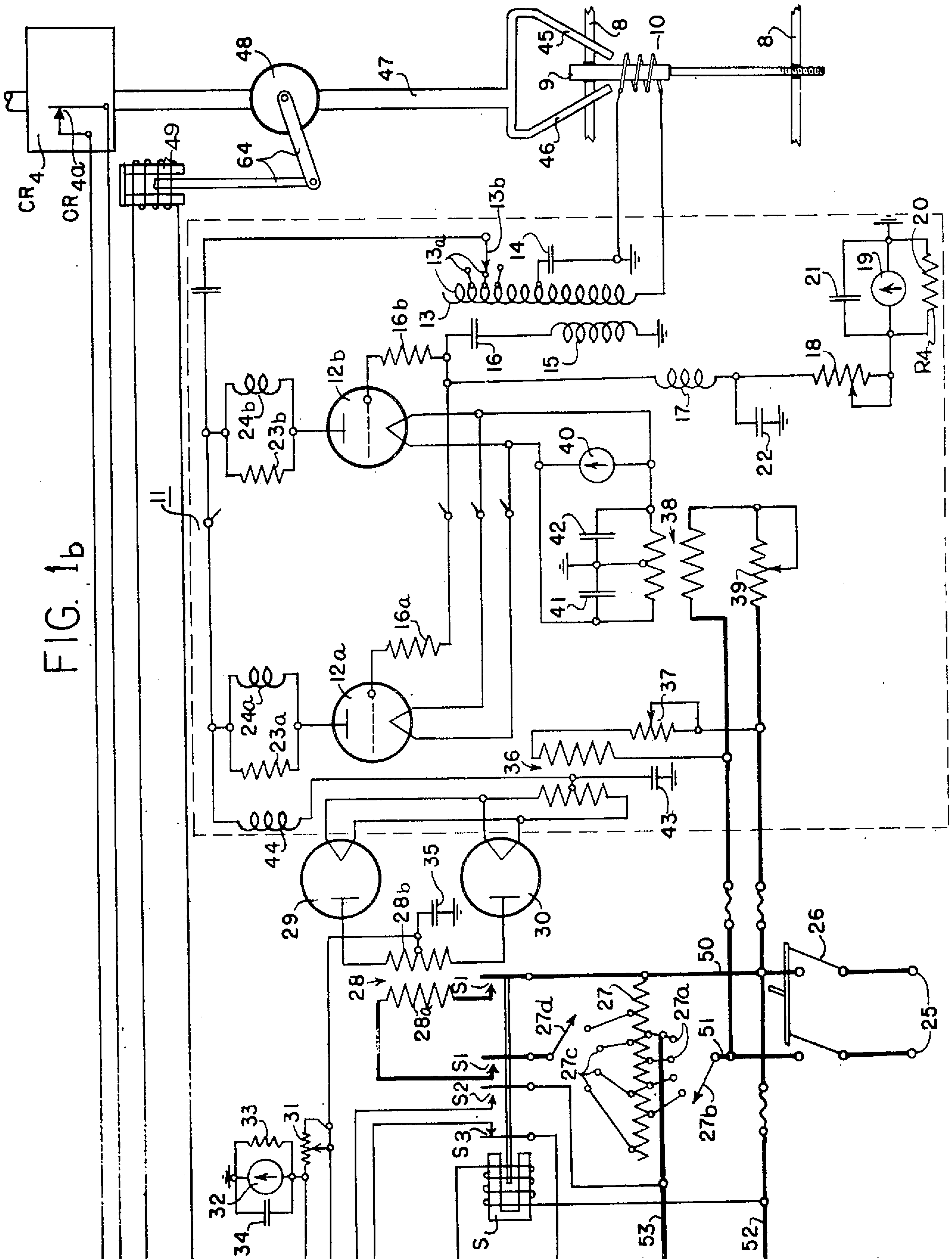

FIG. 1b

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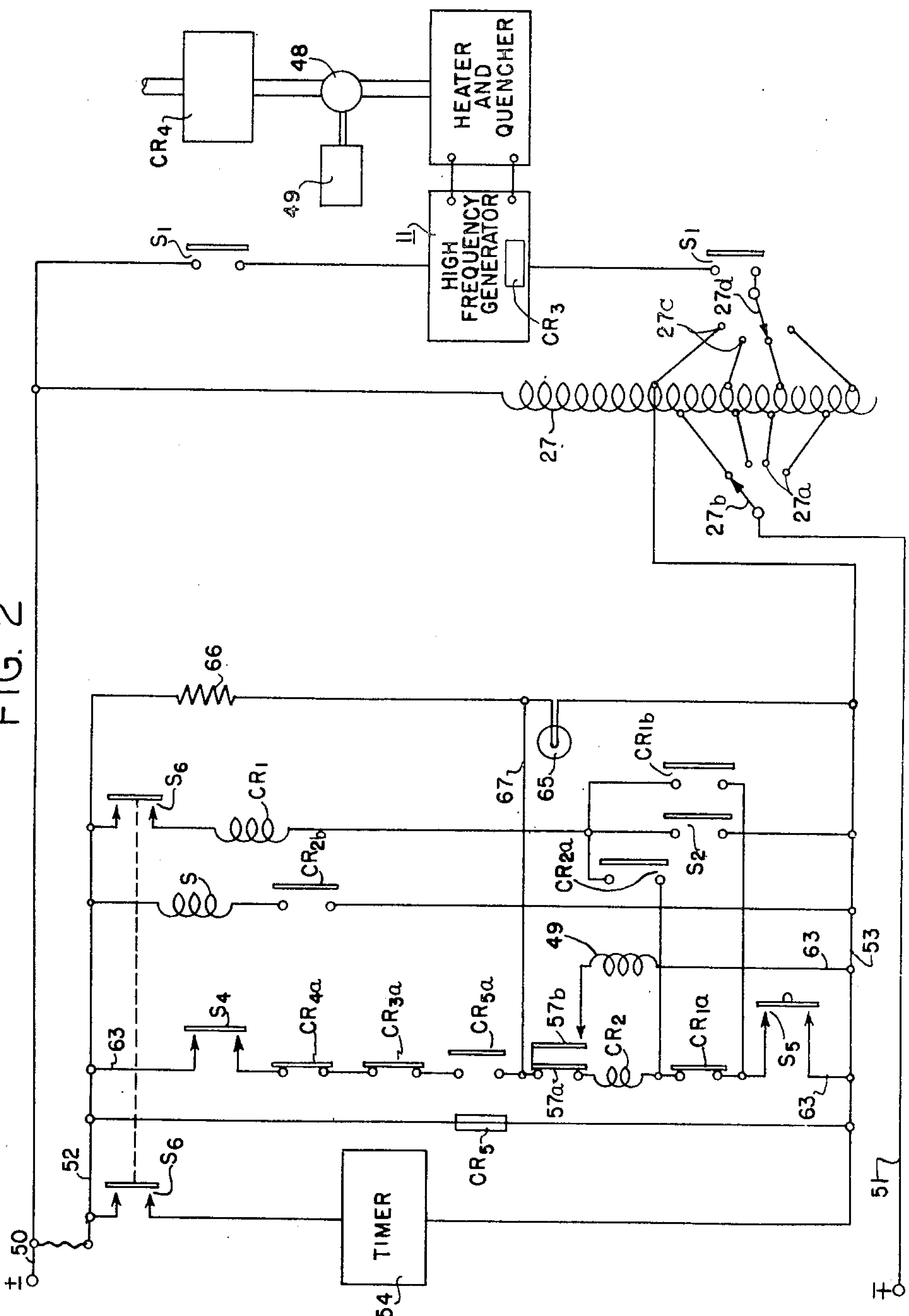
Filed June 7, 1944 3 Sheets-Sheet 3

FIG. 2



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UNITED STATES PATENT OFFICE

2,485,785

HIGH-FREQUENCY INDUCTION HEATING SYSTEM

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Application June 7, 1944, Serial No. 539,106

9 Claims. (Cl. 266—4)

1

This invention relates to high-frequency induction heating systems, and, while it is of general application, it is particularly useful in such systems of the type suitable for the surface treating of a large quantity of machine or tool elements or stock on a production basis. The invention is concerned primarily with control and indicating systems incorporated in such heating systems and with provisions for adapting it to the treatment of work pieces having a wide range of high-frequency impedances.

In the heat treatment of a large quantity of standardized machine or tool elements or stock by a high-frequency induction heating system, it is desirable that the timing of the various phases of the heat-treating cycle be completely automatic after a manual initiation of the cycle, as distinguished from what might be termed a custom treatment of individual special parts and assemblies involving an adjustment of the settings of the various portions of the heating apparatus for each piece being treated and a careful watching of the heating cycle by the operator. Automatic control of the heat-treating cycle greatly increases the rate of treatment on a mass production basis and also insures greater uniformity of heat treatment by largely eliminating the human factor. At the same time, it is desirable to be able to adjust the various phases of the heat-treating cycle to accommodate the system to various types of heat treatments and to various types of work pieces. Furthermore, it is desirable to be able to adjust the coupling of the system with the work pieces to compensate for the variations in the high-frequency impedances of the work pieces.

It is an object of the invention, therefore, to provide a new and improved high-frequency induction heating system including provisions for automatically controlling the heat-treating cycle of the work piece and one which is particularly useful for the heat treatment of a large quantity of similar elements on a production basis.

It is another object of the invention to provide an improved high-frequency induction heating system including a novel indicating system for giving an indication, preferably visual, of the particular one of several phases of the heat treating cycle taking place.

It is another object of the invention to provide a new and improved high-frequency induction heating system which is particularly suitable for treatment of work pieces having a wide range of high-frequency impedances.

In accordance with the invention, in a high-

2

frequency induction heating system including a heating inductor and a source of high-frequency energization therefor, there is provided a control system comprising manually operable circuit-controlling means and timing means having a normal cycle of operation between first and second operating conditions. The control system also includes circuit-control means responsive jointly to the timing means and the manually operable means for controlling the energization of the inductor, and relay means energized simultaneously with energization of the inductor for preventing a repetition of the heating cycle without a second operation of the manually operable means.

Further in accordance with the invention, in a high-frequency induction heating system including a heating inductor, a source of high-frequency energization therefor, and fluid quenching apparatus, there is provided a control system comprising timing means having first and second operating conditions with independent time delays in operating between said conditions in opposite senses. The control system also includes means responsive to operation of the timing means from the first condition to the second condition for determining the heating period of the inductor and means responsive to the operation of the timing means from the second condition to the first condition for determining the period of operation of the quenching apparatus.

Further in accordance with the invention, in a high-frequency heating system including a heating inductor and a source of high-frequency energization therefor, there is provided a control system comprising a supply circuit, a control circuit for controlling the energization of the source from the supply circuit and one or more protective devices for the system including circuit-controlling means in the control circuit. The control system also includes an indicating device energized from the supply circuit for giving an indication of its energization and means controlled by the control circuit for modifying the energization of the indicating device upon operation of one or more of the protective devices to give an indication thereof.

The invention, both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the specification taken in connection with the accompanying drawings, in which:

Figs. 1*a* and 1*b*, when laid end to end in the order named, illustrate one embodiment of the present invention; and

Fig. 2 is an across-the-line diagram of the apparatus shown in Figs. 1*a* and 1*b*.

Referring now to Figs. 1*a* and 1*b* of the drawings, there is there represented partially schematically a complete high-frequency induction heating system for treating work pieces having a wide range of high-frequency impedances. This system includes a heating inductor 10 for receiving a work piece 9 disposed in a positioning jig 8, 8 and a source of high-frequency energization therefor comprising a vacuum tube oscillation generator 11. This generator comprises a plurality of vacuum tubes in parallel, only two of which 12*a*, 12*b* are shown for the sake of simplicity, although in practice a larger number may be utilized to provide the required power output. The common output circuit of the tubes 12*a*, 12*b* includes the frequency-determining circuit of the generator consisting of an auto-transformer 13, a tuning condenser 14 and the heating inductor 10 connected in a series circuit. The auto-transformer 13 is provided with taps 13*a* and an adjustable contact 13*b* to provide an adjustable coupling between the common output circuit of the vacuum tubes and the inductor 10, a portion of the auto-transformer being included in the frequency-determining circuit of the oscillation generator. Coupled to the auto-transformer 13 is a secondary feed-back winding 15 which is coupled to the input electrodes of the tubes 12*a*, 12*b* through a coupling condenser 16 and grid resistors 16*a*, 16*b*, respectively. A proper bias for the tubes 12*a*, 12*b* is developed across a grid-leak circuit comprising a high-frequency choke coil 17, an adjustable resistor 18 and grid-current meter 19 shunted by a resistor 20 and condenser 21. A by-pass condenser 22 is connected between the junction of the choke coil 17 and resistor 18 to ground. Parasitic suppressors comprising a parallel-connected resistor 23*a* and inductor 24*a* and a parallel-connected resistor 23*b* and inductor 24*b* are individually connected in the anode circuits of the tubes 12*a*, 12*b*, respectively, to suppress parasitic oscillations between the tubes.

The power for energizing the high-frequency generator 11 is derived from supply terminals 25, which may be a conventional 60-cycle, 220-volt system, through a switch or circuit breaker 26, a power auto-transformer 27, described more fully hereinafter, a rectifier transformer 28 comprising a primary winding 28*a* and a bi-phase secondary winding 28*b*, and a pair of rectifier tubes 29 and 30, preferably of the hot-cathode vapor-electric type. The tubes 29 and 30 with the winding 28*b* are connected as a conventional full-wave rectifier circuit, the neutral point of winding 28*b* being connected to ground through an adjustable resistor 31 and an ammeter 32 shunted by a resistor 33 and by-pass condenser 34, and being by-passed to ground for high-frequency currents by means of a condenser 35. The filaments of the tubes 29 and 30, or in case these tubes are of the indirectly heated cathode type, their cathode heaters, are energized through a filament transformer 36 connected across the supply terminals 25 through an adjustable resistor 37 and the switch 26. Similarly the filaments of the tubes 12*a*, 12*b*, or in case these tubes are of the indirectly heated cathode type, their cathode heaters, are energized from the supply terminals 25 through a filament transformer 38 and an adjustable resistor 39 and the switch 26. A voltmeter 40 is connected across the filament circuit of the tubes 12*a*, 12*b* while the secondary winding of the transformer 38 is by-passed for high-frequency currents by condensers 41 and 42 connected in series. The adjustable resistors 37 and 39 are provided to control the filament voltages of tubes 12*a*, 12*b*, 29 and 30 to the optimum value consistent with the operating conditions of these tubes to insure maximum life expectancy of the tubes.

High-potential unidirectional current is applied to the anode circuits of tubes 12*a*, 12*b* from the midpoint of the secondary winding of filament transformer 36, by-passed to ground by filter condenser 43, through a high-frequency choke coil 44 and the suppressors 23*a*, 24*a* and 23*b*, 24*b*.

From the description above it will be seen that the direct-current circuit of the rectifier 28, 29, 30 and the oscillation generator 11 may be traced from the midpoint of the secondary winding of the rectifier filament transformer 36 through the high-frequency choke coil 44, the suppressor circuits 23*a*, 24*a* and 23*b*, 24*b* and the tubes 12*a*, 12*b*, respectively, in parallel, through the midpoint of the secondary winding of the filament transformers 38 to ground, thence through the ammeter 32, resistor 31, midpoint of the secondary winding 28*b*, through one or another of the rectifier tubes 29, 30 back to the midpoint of the secondary winding of filament transformer 36.

In order to quench and temper the work piece after heat treatment, the system also includes a quenching apparatus comprising the nozzles 45 and 46 connected to a fluid supply pipe 47 which is connected through a valve 48 to a source of water or other cooling fluid. The valve 48 is connected to be operated by the electromagnet 49 and actuating mechanism 64.

The induction heating system also includes a control system for initiating and controlling the heating and quenching cycle. This control system comprises a supply circuit consisting of conductors 50 and 51 connected to the supply terminals 25 through the switch 26. The primary portion of the autotransformer 27 comprising taps 27*a* and an adjustable contact 27*b* is connected across the supply circuit 50, 51, while a secondary portion of the autotransformer 27 comprising taps 27*c* and an adjustable contact 27*d* are connected across the primary winding 28*a* of the transformer 28 through the normally-open contacts S_1 of an electromagnetic switch or contactor S.

The control system may be more readily traced from the simplified across-the-line diagram of Fig. 2, which is the exact electrical equivalent of Figs. 1*a* and 1*b* with the various relays and switches and their respective contacts disengaged and with the various portions of the control system arranged in the order of their sequence of operation.

Referring then to Figs. 1*a*, 1*b* and to Fig. 2, the control system includes a pair of control busses 52 and 53, the bus 52 being connected to the supply circuit conductor 50 through a fuse, if desired, and the bus 53 being connected to a tap 27*a* of the autotransformer 27. Between the control busses 52, 53 is connected a timer 54 through the contacts S_6 of a manually operable switch. While the timer 54 may be of any of several types well known in the art, there is illustrated in Fig. 1*a* an electronic timer of the type disclosed and claimed in copending application Serial No.

539,104, filed June 7, 1944, now Patent 2,396,898, and assigned to the same assignee as the present application.

The timer 54 comprises a vacuum tube repeater 55 connected to be excited from the control bus 52 through the switch S_6, a rectifier tube 56 and a relay 57 having normally closed contacts 57*a*, 57*c*, and 57*d*, and normally open contacts 57*b*. The anode current excitation of the tube 55 is shunted by a smoothing or filtering condenser 58. A suitable negative grid bias is developed for the control electrode of the tube 55 by means of an auxiliary rectifier 59 having a load circuit comprising a resistor 60 and filter condensers 61 and 62. The resistor 60 is provided with an adjustable tap 60*a* by means of which an adjustable negative bias may be applied to the control electrode of tube 55 through either a resistor R_1 or an adjustable resistor R_q through a control circuit to be described hereinafter. The control electrode of the tube 55 is also connected to a time-constant circuit comprising an adjustable resistor R_h condenser C and the normally closed contacts 57*c* of relay 57.

The control system, which may be traced more readily from the simplified diagram of Fig. 2, also includes a control circuit 63 for controlling the energization of the high-frequency generator 11 from the supply circuit of 50, 51. This control circuit 63 extends between the busses 52 and 53 and includes a manually operable circuit control means, such as a treadle-operated switch S_5, for initiating the heating and quenching cycle; the contacts 57*a* and 57*b* of the timer 54 which, as described hereinafter, has a normal cycle of operation between its energized and deenergized operating conditions; and circuit control means responsive jointly to the relay 57 of the timer 54 and the manually operable switch S_5 for controlling the energization of the inductor 10 from the supply circuit. This latter circuit-control means comprises a control relay CR_2 having an operating winding included in the control circuit 63 and the electromagnetic switch S having a winding energized from the control busses 52, 53 through the normally-open contacts CR_{2b} of the relay CR_2. This control circuit includes also the winding of actuating mechanism 49 energized through the normally-open contacts 57*b* of relay 57.

The control system also include relay means energized simultaneously with the energization of the inductor for preventing repetition of the heating and quenching cycle without a second operation of the manually operable means. This relay means consists of a relay CR_1 having a winding energized from the control busses 52, 53 through the manually operable switch S_6 and the auxiliary normally open contacts S_2 of the electromagnetic switch S and therefore energized simultaneously with the heating inductor upon the closing of the switch S. The relay CR_1 is provided with a holding circuit which includes the manually operable switch S_5 and its own normally-open contacts CR_{1b}. The relay CR_1 is also provided with normally-closed contacts CR_{1a} included in the control circuit 63 with the winding of the relay CR_2 in series with the manually operable switch S_5 which, as will be pointed out hereinafter, effectively prevents a repetition of the heating and quenching cycle of the system so long as the manually operable switch S_5 is held closed. The relay CR_2 is also provided with a holding circuit including its normally-open contacts CR_{2a} and the auxiliary contact S_2 of the switch S, this holding circuit being effective to maintain the relay CR_2 energized under the control of the relay 57 of timer 54 even though the switch S_5 is closed only momentarily.

The control system includes a plurality of protective devices for the system, each of which includes circuit-controlling contacts in series in the control circuit 63 between the control busses 52, 53. For example, the protective devices may comprise a switch S_4 mechanically interlocked with the door of the housing for the apparatus to insure that the system as a whole is deenergized so long as the door is open for maintenance or repair. In order to insure the flow of cooling water through the quenching apparatus 45—48, inclusive, there is provided a water flow relay CR_4 having normally closed contacts CR_{4a} in series in the control circuit 63, these contacts opening upon the failure of the water supply. Also, there is provided an overload protective relay CR_3 having a winding connected in series with the direct-current circuit of the power rectifier and shunted by the adjustable resistor 31. This relay is designed to open its normally-closed contacts CR_{3a} in control circuit 63 upon the occurrence of an overload in the heating system. Also, there is provided a time-delay relay CR_5, which may be a bi-metallic thermal relay, connected between the control busses 52, 53 and having normally open contacts CR_{5a} included in series in the control circuit 63 and effective to delay the excitation of the control system and the energization of the high-frequency generator 11 until the heaters of the several tubes of the system have reached normal operating temperatures.

The control system also includes an indicating device, such as a lamp 65, connected between the control busses 52, 53 through an impedance means such as a resistor 66 for giving an indication of the energization of the control busses 52, 53. Resistor 66 has a value which normally reduces the illumination of lamp 65 substantially below its normal value. The control system also includes means controlled by the control circuit 63 for modifying the energization of the indicating lamp 65 upon operation of any one or more of the protective devices described. As illustrated, this comprises the connection 67 between the junction of the lamp 65 and resistor 66 and the point in the control circuit including the contacts of all of the protective devices, whereby, when the contacts of these devices are all closed, this portion of the control circuit 63 is effective to by-pass or short-circuit the resistor 66 in series with the lamp to increase its illumination to normal. This connection also has the effect that, if the manually operable switch S_5 is operated while the contacts of any one or more of the protective devices are open, the lamp 65 is effectively deenergized or short-circuited through the portion of the control circuit including the winding of the relay CR_2, the contacts CR_{1a} and the switch S_5.

Considering now the operation of the high-frequency generator and its associated heating inductor, it will be seen that the autotransformer 27, the transformer 28 and the tubes 29 and 30 comprise a conventional rectifier circuit for deriving from the supply terminals 25 a source of high-potential unidirectional current. This current, or a predetermined portion thereof, flows through the meter 32 which gives an indication representative of the high-frequency current being supplied to the heating inductor 10. This high-voltage rectified current is supplied to the high-frequency generator 11 which constitutes an oscillator of conventional type. The feed back between the anode circuits of the tubes 12a, 12b through the windings 13 and 15 maintain the apparatus in oscillation at the frequency determined by the constants of the circuit 13, 14, 10. Since the oscillating current in the frequency-determining circuit of the generator flows in series through the heating inductor 10, there is developed thereby a high-frequency electromagnetic field which is effective to heat the work piece 9.

The adjustable tap 27b of the autotransformer 27 is utilized to compensate for fluctuations in the line voltage of the supply terminals 25. Similarly, the adjustable contact 27d of the autotransformer 27 is utilized to select various anode voltages for the high-frequency generator to control the intensity of the high-frequency field developed by the inductor 10 and thus the nature of the heat treatment.

In practice it is found that the high-frequency impedance of the work piece 9 may vary considerably in accordance with its dimensions and physical composition. This variation in impedance is reflected into the frequency-determining circuit of the generator 11 and, unless the effects of such variation are compensated, affects the efficiency of the oscillator. The effects of such variations are compensated and a high oscillator efficiency is maintained by adjusting the coupling between the frequency-determining circuit and the output circuit of the tubes 12a, 12b. This coupling may be either conductive, that is with the elements directly in circuit with each other, or it may be impedance coupling or inductive or transformer coupling or a combination of these. In the circuit illustrated, this coupling is adjusted by adjustment of contact 13b of autotransformer 13, which is effective to match the load impedance, as affected by the work piece 9, to the circuit parameters of the oscillator.

It is well known that, in the operation of vacuum tubes in parallel there often are developed high-frequency parasitic or circulating currents between the tubes which, in a conductive state, have a relatively low impedance to such circulating currents in the system described. Such parasitic oscillations are suppressed by the parasitic suppressors 23a, 24a and 23b, 24b individually connected in the anode circuits of tubes 12a, 12b respectively. The constants of these suppressor circuits are selected so that they do not add considerably to the impedance of the tube circuits at the operating frequency of the generator 11, but do offer a substantial impedance to parasitic circulating currents between the tubes.

The operation of the electronic timer 54 is explained in detail in the above mentioned copending application Serial No. 539,104. However, in brief, upon closing of the switch S_6 there is developed across the resistor 60 a negative unidirectional bias potential by the rectifier 59. This potential is applied over the circuit including the resistor R_1 and R_q in parallel through the contact S_3 of the switch S to the control electrode of tube 55. The magnitude of this negative bias is selected by appropriate adjustment of the tap 60a to maintain the tube 59 non-conductive. When the manually operable switch S_5 is operated and thereby opens the contacts S_3 of switch S, as explained hereinafter, the control electrode of tube 55 is disconnected from the negative bias derived from resistor 60 and the charge built up on condenser C gradually discharges through the

adjustable resistor R_h. When this negative bias has decreased to the point that the tube 55 becomes substantially conductive, the space current of the tube 55 is effective to pick up the relay 57, thereby opening the normally closed contacts 57c in the discharge circuit of condenser C. As explained hereinafter, the operation of the relay 57 is also effective to open the switch S, thereby closing the contacts S_3 between the control electrode of tube 55 and the charging resistor R_q, while the normally-open contacts 57d in series with the resistor R_1 are opened. The condenser C is thereupon gradually re-charged by the potential at the tap 66a through the adjustable resistor R_q until the bias across the condenser is sufficient substantially to cut off the space current of tube 55, whereupon the relay 57 drops out and the timer 54 is in condition for a repetition of this cycle, unless interrupted by the control system described hereinafter.

As the electronic timer 54 is utilized in the system described, the resistor R_1 has a relatively small value so that, upon initiation of the operation of the timer by closing of switch S_6, the condenser C in the circuit of the control electrode of tube 55 is rapidly charged to its final value. Furthermore, the discharging of the condenser C through the resistor R_h is utilized to determine the heating period of the heating system while the subsequent charge of the condenser C through the resistor R_q is utilized to determine the period of operation of the quenching apparatus. It is desirable that these two periods be subject to independent adjustment by adjustment of the values of the resistors R_h and R_q, respectively. However, neglecting the resistor R_1, during the charging period the resistor R_q is in series with the resistor R_h across the source of bias potential and these two resistors comprise a voltage divider so that the final voltage across the condenser C would be only a fraction of that derived from tap 60a and would be affected by the setting of the resistor R_q. However, the addition resistor R_1 of a very much lower value than R_q and R_h effectively by-passes the resistor R_q during the initial charging of the condenser C at the beginning of each operating cycle. By this means the heating and quenching intervals can be independently adjusted. Thus it is seen that the timer 54 including the relay 57 constitutes a time-delay relay having a normal cycle of operation between circuit opening and circuit closing positions of contacts 57a and, in case both contacts 57a and 57b are utilized, having a normal cycle of operation between two circuit closing positions.

Coming now to the operation of the control system embodied in the heating system of the invention, which may be most readily understood by reference to Fig. 2 of the drawings. If completely manual operation of the system is desired, the switch S_6 is left open. If then the contacts of the several protective devices are closed in the circuit 63, that is, the door switch S_4 is closed, the water flow relay CR_4 responds to a normal water supply, the overload relay CR_3 is not operative and the time-delay thermal relay CR_6 has operated to close its contacts, a circuit is completed through the normally closed contacts 57a of relay 57, the operating coil of relay CR_2 and the normally closed contacts CR_{1a} to the manually operable switch S_5. Closing of the switch S_5 is then effective to pick up the relay CR_2 which, as indicated in the next branch of the circuit, energizes the winding of the electromagnetic switch or contactor S which thereupon closes its contacts S_1 to energize the high-frequency generator 11 to heat the work piece 9. Under this condition the energizaton of the high-frequency generator 11 and the heating of the work piece are under the complete control of the manually operable switch S_5.

In case it is desired to have the heating and quenching of the work piece under the control of the timer 54, the switch S_6 is closed. Upon closing of the manually operable switch S_5 the heating cycle is initiated as described above. In this instance, however, upon the operation of the relay CR_2 and the switch S, the winding of the control relay CR_1 is energized through the contact S_2 and a holding circuit for the relay CR_2 is established around the manually operable switch S_5 through the contacts CR_{2a} and S_2 so that the relay CR_2 and the switch S remain closed even after the release of the switch S_5.

As the relay CR_1 picks up, it opens its contacts CR_{1a}, thus interrupting the energizing circuit for the winding of the relay CR_2 except for the holding circuit described above. At the same time CR_1 closes its contacts CR_{1b} and establishes a holding circuit for itself through these contacts and the manually operable switch S_5. The effect of this holding circuit is that, so long as the switch S_5 is held closed, only a single cycle of the control system is effected. This is true since, as soon as the relay contacts 57*a* are opened by the timer, the relay CR_2 and the switch S both drop out, the holding circuit for the relay CR_2 being broken at the contacts CR_{1a}. However, the relay CR_1 is still energized through its holding circuit described and its normally closed contacts CR_{1a} are held open and prevent reclosing of relay CR_2 and switch S. In other words, during automatic operation the manually operable switch S_5 only initiates the cycle of the control system, but has no effect on the durations of the various phases of the control cycle, while the relay CR_1 prevents a repetition of the cycle.

The heating of the work piece 9 initiated as described above continues until the timer 54 picks up the relay 57 to open the contacts 57*a* at the completion of the discharge of the condenser C through resistor R_h, which operation terminates the heating period. At the same time the relay 57 closes its contacts 57_b to energize the winding of the actuating mechanism 49 of the quenching valve 48 to apply quenching fluid to the work piece 9. When the condenser C has been charged through the resistor R_q to a value such that the tube 55 deenergizes the relay 57, it drops out, opening its contacts 57*b* to terminate the quenching operation and close the contacts 57*a*. The control system is now in condition for the repetition of the heating and quenching cycle, which will usually be initiated only after replacement of the work piece 9 by an untreated work piece. This restoration of the control system to its normal condition is, however, conditioned upon the release of the manually operable switch S_5 as described above. If by chance this switch is maintained closed, the system undergoes a single cycle of operation and is then locked out.

The pilot lamp 65 of the control system is adapted to have its energization, and therefore its illumination, modified greatly upon operation of one or more of the protective devices having circuit-controlling contacts in the control circuit 63 to give distinctive indications of such operations. Specifically, the lamp 65 is energized from the control busses 52, 53 through the impedance or resistor 66 and therefore initially operates with reduced illumination. When the protective devices S_4, CR_4, CR_3 and CR_5, described above, all assume their safe positions, their respective contacts are closed and the portion of the control circuit 63 including them is effectively connected around or short-circuits the resistor 66 to bring up the energization and illumination of the lamp 65 to its normal value. On the other hand, if the switch S_5 is closed while the contacts of any of the protective devices are open, this fact is indicated by extinguishing the lamp 65. This extinguishing is effected by an effective short-circuit of the lamp 65 through the portion of the control circuit 63 including the contacts 57*a* of relay 57, the winding of the relay CR_2, the contacts CR_{1a}, and the switch S_5.

Thus the high-frequency induction heating system described above comprises an arrangement for effectively heating a work piece under optimum operating conditions by compensating for variations in the supply voltage and variations in the high-frequency impedance of the work piece. It also comprises a control system which may be operated either non-automatically, so that the heating and quenching operations can be determined at will by the operator, or automatically, whereby the heating and quenching operations may be adjustably controlled by a timing apparatus included in the control system. The system further includes an indicating device or lamp for giving different distinctive indications of various operating conditions of the system.

While there has been described what is considered to be the preferred embodiment of the invention, it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the spirit or scope of the invention.

What I claim as new is:

1. In a high-frequency induction heating system including a heating inductor and a source of high-frequency energization therefor, a control system comprising, manually operable circuit-control means, timing means having a normal cycle of operation between first and second operating conditions, circuit-control means responsive jointly to said timing means and said manually operable means for controlling the energization of said inductor, and relay means energized simultaneously with energization of said inductor for preventing repetition of the heating cycle without a second operation of the manually operable means.

2. In a high-frequency induction heating system including a heating inductor and a source of high-frequency energization therefor, a control system comprising, manually operable circuit-control means, a time-delay relay having a normal cycle of operation between circuit opening and circuit closing positions, circuit-control means controlled jointly by said relay and said manually operable means for controlling the energization of said inductor, and relay means energized simultaneously with energization of said inductor for preventing repetition of the heating cycle without a second operation of the manually operable means.

3. In a high-frequency induction heating system including a heating inductor and a source of high-frequency energization therefor, a control system comprising, manually operable circuit-control means, a time-delay relay having a normal cycle of operation between circuit opening and circuit closing positions, an electromagnetic switch means having an operating winding energized jointly by means of said relay and said

manually operable means for controlling the energization of said inductor, and relay means energized simultaneously with energization of said inductor fcr preventing repetition of the heating cycle without a second operation of the manually operable means.

4. In a high-frequency induction heating system including a heating inductor and a source of high-frequency energization therefor, a control system comprising, manually operable circuit-control means, a time-delay relay having a normal cycle of operation between circuit opening and circuit closing positions, an electromagnetic switch means having an operating winding energized jointly by means of said relay and said manually operable means for controlling the energization of said inductor, and a relay having a winding energized simultaneously with energization of said inductor and a holding circuit therefor including said manually operable means and having contacts effective upon energization of said relay winding to interrupt the energization of said switch winding through said manually operable means, thereby preventing repetition of the heating cycle without a second operation of the manually operable means.

5. In a high-frequency induction heating system including a heating inductor and a source of high-frequency energization therefor, a control system comprising, manually operable circuit-control means, a time-delay relay having a normal cycle of operation between circuit opening and circuit closing positions, an electromagnetic switch means having an operating winding energized jointly by means of said relay and said manually operable means for controlling the energization of said inductor, a holding circuit for said switch winding including contacts of said switch means, and relay means energized simultaneously with energization of said inductor for preventing repetition of the heating cycle without a second operation of the manually operable means.

6. In a high frequency induction heating system including a heating inductor, a source of high frequency energization therefor and fluid quenching apparatus, the combination of a control system comprising, timing means having a first operating control position and a second operating control position, said timing means having independently controllable time delays in operating from said first position to said second position and from said second position to said first position, means responsive to the operation of said timing means from said first operating control position to said second operating control position for controlling said timing means to determine the heating period of said inductor, and means responsive to the operation of said timing means from said second operating control position to said first operating control position for controlling said timing means to determine the period of operation of the quenching apparatus.

7. In a high frequency inducting heating system including a heating inductor, a source of high frequency energization therefor and fluid quenching apparatus, the combiination of a control system comprising, a timing delay relay operable between two circuit closing positions, said time delay relay having independently controllable time delays in operating from one of said positions to the other of said positions and from the other of said positions to said one of said positions, means responsive to operation of said relay in one direction between said two positions for determining the heating period of said inductor, and means responsive to operation of said relay between said positions in the other direction for determining the period of operation of the quenching apparatus.

8. In a high frequency induction heating system including a heating inductor, a source of high frequency energization therefor and a fluid quenching apparatus, the combination of a control system comprising, a time delay relay operable between two circuit closing positions, said time delay relay having independently controllable time delays in operating in opposite directions between said two positions, electromagnetic switch means having a winding energized through said relay in one of said positions and contact means for controlling the energization of said inductor, and electromagnetic means having a winding energized through said relay in the other of said positions for actuating said quenching apparatus.

9. In a high frequency induction heating system including a heating inductor, a source of high frequency energization therefor and fluid quenching apparatus, the combination of a control system comprising, timing means having a first and second control operating position, said timing means having independently controllable time delays in operating in different directions between said two positions, means responsive to the operation of said timing means from said first operating control position to said second operating control position for controlling said timing means to determine the heating period of said inductor, and means responsive to the operation of said timing means from said second operating control position to said first operating control position for controlling said timing means to determine the period of operation of the quenching apparatus, manually operable means for initiating the heating and quenching cycle, and means energized simultaneously with energization of said inductor for preventing repetition of the heating and quenching cycle without a second operation of said manually operable means.

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