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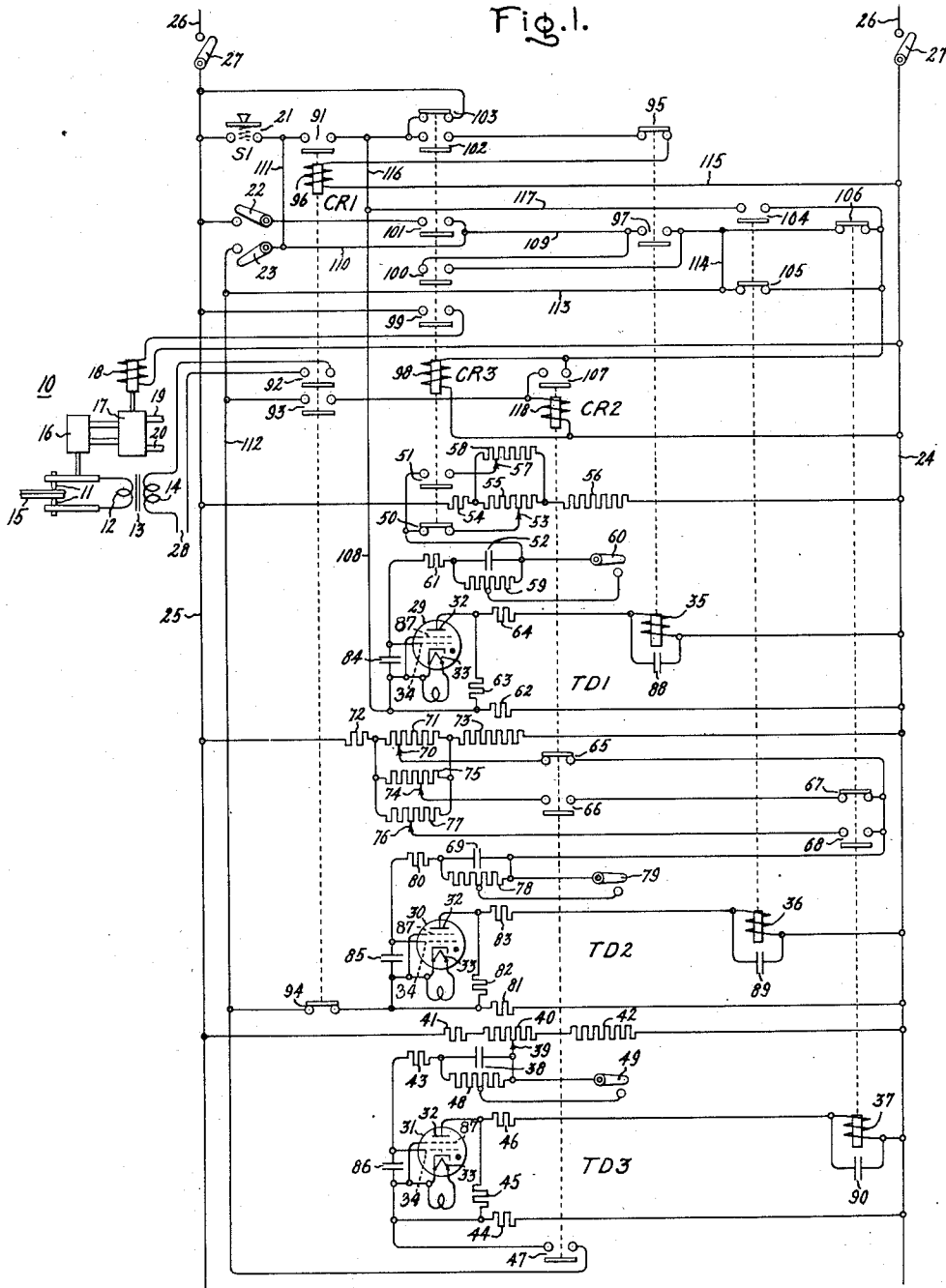
M. E. BIVENS

2,390,981

TIMING APPARATUS

Filed Sept. 30, 1942

2 Sheets-Sheet 1



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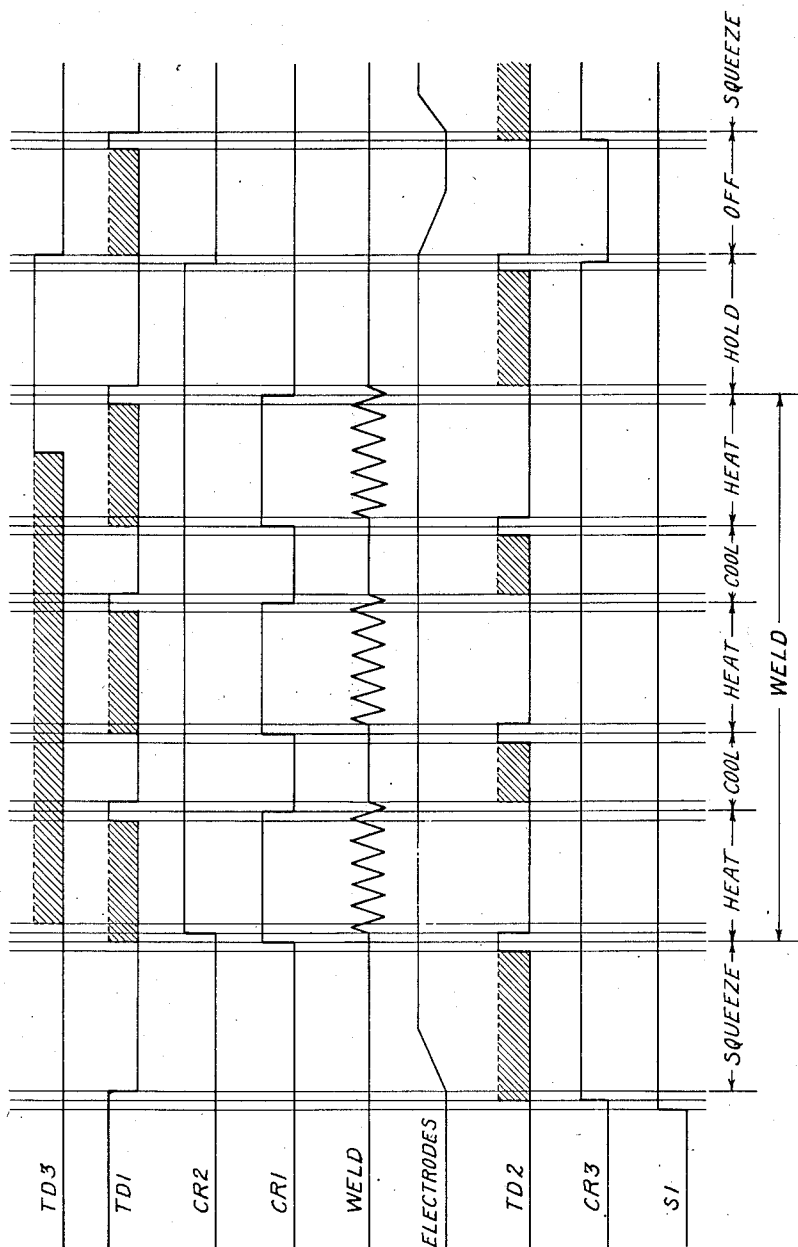
2,390,981

TIMING APPARATUS

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2 Sheets-Sheet 2

Fig. 2.



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UNITED STATES PATENT OFFICE

2,390,981

TIMING APPARATUS

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New York

Application September 30, 1942, Serial No. 460,239

21 Claims. (Cl. 250—27)

My invention relates to timing apparatus, and more particularly to apparatus embodying electric circuits in which electric discharge devices are employed for obtaining desired timing operations.

In industrial control it is frequently desirable to provide apparatus for controlling the sequence and timing of certain operations. For example, in resistance welding, certain operations must follow one another after predetermined adjustable time periods, and a sequence control for such purpose may involve six timing intervals which may be identified as "squeeze," "heat," "cool," "weld," "hold," and "off." The squeeze time allows for the operation of means employed for closing the welding electrodes on the work with desired pressure before the welding current is applied thereto through the electrodes to make a weld. The heat time determines the duration of an impulse of welding current flow, and the cool time determines the time between current impulses when a plurality of current impulses is used for making a weld, as is the case in interrupted spot welding. In interrupted spot welding, a plurality of heat times spaced by one or more cool times is determined by the weld time. The hold time determines the time that the electrodes remain on the work with full pressure after welding current ceases flowing and before the means for pressing the electrodes on the work is operated to release the work. The off time determines the time interval before the means for pressing the electrodes into engagement with the work is again operated when performing repeat operations. Preferably all the above time intervals are independently adjustable.

In the past such a sequence control has been accomplished by six independent timing units. In accordance with my invention a smaller number of timing units is employed for accomplishing the same sequence by causing one or more of the timing units to operate repeatedly with different time settings.

It is an object of my invention to provide a new and improved time delay circuit.

It is also an object of my invention to provide a new and improved timing circuit which operates in accordance with the delayed conduction of an electric discharge device provided with a control element which is selectively connected to a plurality of timing circuits each of which renders it conductive after a predetermined time delay which is different for each of the timing circuits.

A further object of my invention is to provide control apparatus in which a plurality of operations are timed by the alternate operation of a plurality of time delay circuits each of which embodies an electric discharge device provided with a plurality of timing circuits which are selectively connected to the control element of the electric discharge device with which they are associated by switching means controlled by said time delay circuits.

It is also an object of my invention to provide control apparatus in which a time delay circuit embodying an electric discharge device and a plurality of timing circuits for its control element is controlled by a time delay relay which operates to change the connection of the control element of the electric discharge device from one of said timing circuits to another of said timing circuits.

Further objects of my invention will become apparent from a consideration of the electric control diagrammatically represented in Fig. 1 of the accompanying drawings and the sequence chart for this control which is shown in Fig. 2 of these drawings.

In accordance with my invention, the six timing intervals above referred to as employed in making a spot weld are determined by three time delay relays instead of using six for this purpose as in the past. In the system about to be described, one time delay relay determines the heat and off times, another time delay relay determines the squeeze, cool, and hold times, and a third time delay relay determines the weld time. The first and second time delay relays above referred to are arranged to operate with different time delays by reason of a plurality of timing circuits selectively connected to the control elements of the electric discharge devices forming part thereof. Switching means operated by one or more of these relays switch from one timing circuit to another timing circuit prior to the time that the time delay relay controlled thereby is to operate with a new time delay.

In Fig. 1 of the drawings, the welding machine has been diagrammatically represented at 10. It comprises a plurality of electrodes 11 which are connected to the terminals of a secondary 12 of a welding transformer 13 having a primary winding 14. The electrodes are moved toward and away from each other into and out of engagement with the work 15 by a fluid operated mechanism 16 which may be a piston and cylinder arrangement operated by the admission and exhaust of fluid from opposite ends of the cylinder

to actuate a piston located therein. The admission and exhaust of fluid from mechanism 16 are controlled by a valve 17 having an operating winding 18. Valve 17 controls the admission of fluid supply from a pipe 19 to mechanism 16 and its exhaust through a pipe 20.

The operation of the welding machine is controlled by the sequence timer constituting the remainder of Fig. 1 of the drawings. It comprises three time delay relays TD1, TD2, and TD3, and three switching relays CR1, CR2, and CR3. These relays are each provided with contacts which are interconnected with one another and hand operated switches S1, 22, and 23 to constitute a switching means which determines the sequence of operations of the welding machine, namely, the squeeze, heat, cool, weld, hold, and off times above referred to.

The operating windings of the relays as well as the operating winding 18 of valve 17 are connected across and energized from a supply circuit 24, 25 whose connection with a source of alternating current supply 26 is controlled by hand operated switches 27. Welding current is supplied to the primary of the welding transformer 13 from a source of supply 28.

The operations of time delay relays TD1, TD2, and TD3 are controlled by electric discharge devices 29, 30, and 31. Each of these electric discharge devices is provided with an anode 32, a cathode 33, and a control element 34. The operating windings 35, 36, and 37 of these relays are connected in series with the anode-cathode circuits of these electric discharge devices across the supply circuit 24, 25 through switching means comprising their contacts, the contacts of relays CR1, CR2, and CR3 and hand operated switches S1, 22, and 23. The time delays in the operations of relays TD1, TD2, and TD3 are determined by the control voltages applied to the control elements 34 of their electric discharge devices 29, 30, and 31. Relays TD1 and TD2 are provided with a plurality of adjustable timing circuits for applying different control voltages to the control elements of their electric discharge devices 29 and 30 in order to control their operations after different time delays, each of which in itself is adjustable. Time delay relay TD3 is provided with only one adjustable timing circuit.

The delay in the operations of relays TD1, TD2, and TD3 depends on the magnitude of the negative potential of a capacitance which is connected to the control element of the electric discharge device forming part of each relay. This capacitance is charged through the control element circuit of the electric discharge device when its anode-cathode circuit is open and discharged when its anode-cathode circuit is closed at a rate determined by a resistance connected across its terminals.

For example, in the circuit of relay TD3, a capacitance 38 is charged by the control-element-cathode rectification of electric discharge device 31 to impress a negative potential on its control element 34. The magnitude of this negative potential of capacitance 38 is determined by the position of a slider 39 on a resistance 40 of a voltage divider comprising series connected resistances 41, 40, and 42 connected across supply circuit 24, 25. The charging circuit is completed through this voltage divider, slider 39, capacitance 38, a current limiting resistor 43, control element 34, and cathode 33 of electric discharge device 31 and the shunt circuits comprising a

resistance 44 and resistances 45, 46 and operating winding 37 of relay TD3. When the anode-cathode circuit of electric discharge device 31 is open and conductor 25 of the supply conductor is at a positive potential, it will be obvious that the potential to which capacitance 38 is charged will depend on the position of slider 39 on resistor 40. It will amount to the voltage drop across resistor 42 and the right-hand portion of resistor 40 determined by the position of slider 39 thereon. This charging circuit for the capacitance is interrupted, however, when the anode-cathode circuit of electric discharge device 31 is completed, for example, by the closing of contacts 47 of relay CR2 and the consequent connection of the cathode of the electric discharge device through a circuit described below to conductor 25 of the supply circuit. The closure of this switch also impresses a positive alternating current voltage on the control element 34 of the electric discharge device, which in magnitude amounts to the voltage drop across resistor 41 and the left-hand portion of resistor 40 determined by the position of slider 39 thereon. That is, when supply circuit conductor 24 is at a positive potential and a positive potential is consequently applied to the anode 32 of electric discharge device 31, its control element 34 is also at a positive potential relative to its cathode 33 by the above referred to voltage drop across resistor 41 and the left-hand portion of resistor 40. Since resistor 42 is made several times larger in value than resistor 41, the positive potential applied to the control element 34 of the electric discharge device is not effective for rendering this device conductive due to the larger negative potential applied to its control element by capacitance 38. However, capacitance 38 slowly discharges through a resistance 48 connected in shunt there-to and after a predetermined time interval determined by this resistance attains a voltage which is less than the positive voltage applied to the control element of electric discharge device 31 when its anode is at a positive potential and consequently capable of conducting current. The time delay range is determined by the position of slider 39 on resistor 40 of the voltage divider and the value of a discharge resistance 48 in shunt to the capacitance. A switch 49 is provided for increasing the range of adjustment by increasing or decreasing the amount of resistance 48 connected across capacitance 38.

The electric circuits of relay TD3 are more fully described in United States Letters Patent 2,171,348, Elbert D. Schneider, granted August 29, 1939, and assigned to the assignee of this invention.

The timing circuits of time delay relays TD1 and TD2 are similar to the timing circuit just described for relay TD3. Relay TD1 is provided with two of these timing circuits which are selectively connected to the control element 34 of electric discharge device 29 by contacts 50 and 51 of relay CR3. Contacts 50 connect a capacitance 52 to a slider 53 on a resistance 55 of a voltage divider comprising series connected resistances 54, 55, and 56, and contacts 51 connect capacitance 52 in circuit with a slider 57 on a resistance 58 of a voltage divider comprising series connected resistances 54, 58, and 56. As in the case of relay TD3, capacitance 52 of relay TD1 is provided with a discharge resistance 59 and a switch 60 for controlling the amount thereof connected across the terminals of capacitance 52. In like

manner, a current limiting resistance 61 and resistances 62, 63, and 64 are also provided.

Relay TD2 is provided with three of these timing circuits which are selectively connected to the control element 34 of electric discharge device 30 by contacts 65 and 66 of relay CR2 and contacts 67 and 68 of relay TD3. Contact 65 connects a capacitance 69 to a slider 70 on a resistance 71 of a voltage divider comprising series connected resistances 72, 71, and 73. Contacts 66 and 67 of relays CR2 and TD3 connect capacitance 69 to a slider 74 on a resistance 75 of a voltage divider comprising resistances 72, 75, and 73. Contact 68 of relay TD3 connects capacitance 69 to a slider 76 on a resistance 77 of a voltage divider comprising resistances 72, 77, and 73. As in the case of relay TD3, capacitance 69 of relay TD2 is provided with a discharge resistance 78 and a switch 79 for controlling the amount thereof connected across the terminals of capacitance 69. In like manner, a current limiting resistance 80 and resistances 81, 82, and 83 are also provided.

The resistances 63, 82, and 45 connected across the anode-cathode circuits of electric discharge devices 29, 30, and 31 are of a high value and employed in order to insure stability of operation of these devices in response to their control voltages. Capacitances 84, 85, and 86 are connected between the control elements 34 and cathodes 33 of these electric discharge devices for a like purpose, that is, to insure stability of operation. Each of the electric discharge devices is provided with a shield grid 87 which is connected to its cathode. The windings 35, 36, and 37 of the relays TD1, TD2, and TD3 are provided with smoothing capacitances 88, 89, and 90 in view of the fact that these exciting windings are traversed by a pulsating current whose flow is controlled by the electric discharge devices 29, 30, and 31 which act as rectifiers and permit current flow in only one direction, namely from their anodes to their cathodes.

Relay CR1 is provided with holding contacts 91, contacts 92 for controlling the energization of the primary 14 of welding transformer 13, contacts 93 for controlling the energization of relay CR2, and contacts 94 in the anode-cathode circuit of electric discharge device 30. Relay TD1 is provided with contacts 95 in circuit with the control winding 96 of relay CR1 and contacts 97 in circuit with the operating winding 98 of relay CR3 and the anode-cathode circuit of electric discharge device 30. Relay CR3 is provided, in addition to contacts 50 and 51 above mentioned, with contacts 99 in circuit with the operating winding 18 of valve 17, contacts 100 in shunt to contacts 97 of relay TD1, contacts 101 in circuit with switch 22 in shunt to the contacts 21 of the switch S1, contacts 102 in circuit with the operating winding 96 of relay CR1 and contacts 103 in the anode-cathode circuit of the electric discharge device of relay TD1. Relay TD2 is provided with contacts 104 in circuit with the operating winding 96 of relay CR1 and contacts 105 which in conjunction with contacts 106 of relay TD3 control the energization of relays CR3 and CR2. Relay CR2, in addition to contacts 47, 65, and 66 already referred to, is also provided with folding contacts 107.

The control exerted by the several relays and their contacts above identified is not completely described in each instance, and consequently a better understanding of my system will be obtained from a consideration of the operation of

the control apparatus of which they form a part.

In the control apparatus shown in Fig. 1, the various relays are shown in their deenergized positions.

Supply conductors 24 and 25 are energized by closing switches 27 through which they are connected to the source of alternating current supply 26. Upon the closure of switches 27, relay TD1 immediately operates without time delay since its anode-cathode circuit is completed from conductor 24 through its winding 35 and electric discharge device 29, conductor 108 and contacts 103 of relay CR3 to conductor 25 before any negative potential can be built up across condenser 52 by its connection with the voltage dividers 54, 55 and 56 through contacts 50 of relay CR3.

When the operator closes the push-button switch S1 to initiate a welding operation, the prior closure of contacts 97 of relay TD1 completes the energizing circuit for winding 98 of relay CR3 and the anode-cathode circuit of relay TD2. The circuit through winding 98 of relay CR3 extends from conductor 24 through contacts 105 of relay TD2 and parallel connected contacts 106 of relay TD3, contacts 97 of relay TD1, conductors 109, 110 and 111, and contacts 21 of switch S1 to conductor 25. The operating winding 36 of relay TD2 is completed from conductor 24 through electric discharge device 30, contacts 94 of relay CR1, conductors 112, 113 and 114, contacts 97 of relay TD1, conductors 109, 110 and 111 and contacts 21 of switch S1 to conductor 25.

The operation of relay CR3 switches the timing circuit of relay TD1 by opening its contacts 50 and closing its contacts 51. It also opens the anode-cathode circuit of electric discharge device 29 of relay TD1 by opening its contacts 103. It also closes its contacts 100 which are in shunt to contacts 97 of relay TD1 so that the opening of TD1 does not interrupt the energizing circuit for its winding 98 or the winding 36 of relay TD2. It also closes its contacts 99 and thereby connects the operating winding 18 of valve 17 across the supply conductors 24, 25. Valve 17 is consequently operated to supply fluid to the electrode operating mechanism 16 and cause this mechanism to force the electrodes 11 into engagement with the work 15.

Upon completion of the anode-cathode circuit of electric discharge device 30 of relay TD2, this relay begins to time out and after a predetermined time delay period determined by the timing circuit which is connected to its control element through contacts 65 of relay CR2, operates to open its contacts 105 and close its contacts 104.

The operation just described for the various relays is indicated in the sequence chart of Fig. 2 whereupon the closure of switch S1 when TD1 is in its "up" position, relays CR3 and TD2 are energized, and the electrodes are moved toward one another by the operation of mechanism 16 under the control of valve 17. The timing period for TD2 is indicated as a shaded block extending to the right from the beginning of the squeeze period, which is initiated by the operation of valve 17 to bring the electrodes into engagement with the work. The movement of these electrodes into engagement with the work 15 is indicated in the sequence chart by the sloping portion of the line labeled "Electrodes." Welding current does not yet flow, and neither of relays CR1, CR2 or TD3 are energized, as indicated by

the straight lines labeled "Weld," "CR1," "CR2" and "TD3" of this sequence chart.

The squeeze period which is provided for bringing the electrodes into positive engagement with the work terminates with the operation of relay CR1 which initiates the flow of welding current shown in the chart by a zig-zag line which indicates cycles of current flow. When relay TD2 operates and closes its contacts 104, a circuit through the operating winding 96 of relay CR1 is completed from conductor 24 through conductor 115, winding 96, contacts 95 of relay TD1, contacts 102 of relay CR3, conductors 116 and 117, contacts 104 of relay TD2, contacts 106 of relay TD3, contacts 100 of relay CR3, conductors 109, 110 and 111 and contacts 21 of switch S1 to conductor 25. The closure of contacts 104 of relay TD2 also completes the anode-cathode circuit of electric discharge device 29 of relay TD1 from conductor 24 through the operating winding 35 and electric discharge device 29 of relay TD1, conductors 108 and 117, contacts 104 of relay TD2, contacts 106 of relay TD3, contacts 100 of relay CR3, conductors 109, 110 and 111 and contacts 21 of switch S1 to conductor 25. Relay TD1 consequently starts timing out under the control of its timing circuit completed by contacts 51 of relay CR3.

The operation of relay CR1 closes its contacts 91 and opens its contacts 94. The opening of contacts 94 deenergizes relay TD2, and this relay consequently opens its contacts 104 and closes its contacts 105. The energization of relay TD1 is nevertheless maintained as is the energization of relay CR1 by the closure of its contacts 91.

The operation of relay CR1 also closes its contacts 92 which completes the connection of the primary 14 of the welding transformer 13 to the source of supply 28. Relay CR1 also closes its contacts 93 and completes the energizing circuit of relay CR2 from conductor 24 through the operating winding 118 of relay CR2, contacts 93 of relay CR1, conductors 112, 113 and 114, contacts 100 of relay CR3, conductors 109, 110 and 111 and contacts 21 of switch S1 to conductor 25.

The operation of relay CR2 closes its holding contacts 107 which places its operating winding 118 in a shunt circuit with the operating winding 98 of relay CR3. It also opens its contacts 65 and closes its contacts 66 to complete a new timing circuit for relay TD2 through the closed contacts 67 of relay TD3. It also closes its contacts 47 and thereby completes the anode-cathode circuit of the electric discharge device 31 of relay TD3 as follows: From conductor 24 through the winding 37 and electric discharge device 31 of relay TD3, contacts 47, conductors 112, 113 and 114, contacts 100 of relay CR3, conductors 109, 110 and 111 and the contacts of switch 21 to conductor 25. Relay TD3 consequently starts timing out.

The conditions just described are illustrated in the sequence chart as occurring between squeeze and heat times.

After a timing period determined by the timing circuit of relay TD1 which is completed through contacts 51 of relay CR3, relay TD1 operates to open its contacts 95 and close its contacts 97. The closure of contacts 97 has no effect since the parallel connected contacts 100 of relay CR3 are also closed. The opening of contacts 95 deenergizes relay CR1 which thereupon opens its contacts 91, 92 and 93 and closes its contacts 94. The closing of contacts 94 reenergizes relay TD2 which immediately starts timing

out with a different delay since the control element of its electric discharge device 30 is now connected to a timing circuit completed by the closure of contacts 66 of relay CR2 and contacts 67 of relay TD3. The opening of contacts 93 of relay CR1 has no effect on the energization of relay CR2 whose operating winding 118 has been placed in parallel with the operating winding 98 of relay CR3 by the closure of contacts 107 of relay CR2. The opening of contacts 92 of relay CR1 interrupts the flow of welding current and consequently terminates the heat period. Meanwhile, relay TD3 is timing out as indicated by the shaded portion in the sequence chart of Fig. 2.

After the new time delay imposed on relay TD2, it operates and closes its contacts 104 thereby terminating the cool period and initiating another heat period.

This second heat period is followed by a second cool period, which in turn is followed by another heat period, during which the relays previously considered in connection with the first heat and cool periods operate in the manner above described.

During the last heat period, relay TD3 times out and operates, closing its contacts 68 and opening its contacts 67 and 106. The closure of contacts 68 and the opening of contacts 67 of relay TD3 connects the third timing circuit of relay TD2 to the control element 34 of its electric discharge device 30. Meanwhile, during this last heat period, relay TD1 is timing out and eventually operates to open its contacts 95. The opening of these contacts deenergizes relay CR1, which by opening its contacts 92 terminates the last heat period by disconnecting the source of supply 28 from the primary 14 of the welding transformer 13. The closure of contacts 94 of relay CR1 completes the anode-cathode circuit of electric discharge device 30 of relay TD2, which after a new timing period operates and opens its contacts 105 and closes its contacts 104.

The concurrent opening of contacts 105 of relay TD2 and contacts 106 of relay TD3 deenergizes relays CR2 and CR3. Upon deenergization, relay CR2 again connects the squeeze timing circuit of relay TD2 through its contacts 65 and opens the anode-cathode circuit of the electric discharge device 31 of relay TD3 and thereby deenergizes its operating winding 37. Relay TD3 consequently closes its contacts 106. The deenergization of relay CR3 causes it to close its contacts 50 which connect the off timing circuit of this relay to the control element 34 of its electric discharge device 29. The closure of contacts 103 of relay CR3 also completes the anode-cathode circuit of the electric discharge device 29 of relay TD1, which after the off timing period will energize the operating winding 35 of relay TD1 and cause this relay to close its contacts 97 and open its contacts 95.

The deenergization of relay CR3 also causes it to open its contacts 99 and thereby deenergize the winding 18 of valve 17. This valve will thereupon cause mechanism 16 to withdraw electrodes 11 from the work 15 so that it may be removed or shifted relatively to the electrodes for another welding operation.

If the contacts 21 of switch S1 are maintained closed, after the time delay period of relay TD1, the sequence of operations will be repeated again.

The above operation of the system has been described when the contacts 21 of switch S1 are maintained closed by the operator. If switch 22

were closed, it would only be necessary for the operator to maintain switch S1 closed until relay CR3 had operated, closing its contacts 101. In which case, the various circuits traced previously instead of being completed by conductors 110 and 111 and contacts 21 of switch S1 would be completed through contacts 101 of relay CR3 and switch 22. Consequently, switch 22 permits a sequence of operations to be completed by momentary closure of switch S1.

Switch 23, when closed, completes a shunt circuit about the contacts 97 of relay TD1. Consequently, it is possible to initiate an operation with switch 23 closed without waiting for the time delay period imposed by relay TD1. Furthermore, for repeat operations, if switch 23 is closed, relay TD2 is maintained energized and consequently eliminates the squeeze period imposed by this relay in the operation above described.

The time delay relays TD1, TD2 and TD3 form part of a system in which switching means controlled by these relays impose a desired sequence of timed operations. It is, of course, apparent that time delay relays each provided with a plurality of timing circuits may be interconnected in another control system for accomplishing another sequence of timed operations without in any way departing from my invention.

Furthermore, relays TD1, TD2 and TD3 have each been considered above as an entity in order to facilitate description thereof. It is to be understood, however, that each of them may be considered as a relay having an operating winding whose energization is controlled by a time delay circuit embodying the electric discharge device associated therewith as defined in some of the claims appended hereto.

It is obvious that where a plurality of timing circuits is employed, a single voltage divider may be employed if a plurality of sliders engaging it are used in place of a slider engaging each of a plurality of parallel connected resistors such as described above. It is also obvious that the voltage divider need not be composed of resistances such as described since any other suitable impedance elements or sources of voltage may be used.

In the system disclosed, the electric discharge devices 29, 30 and 31 are of the type employing an ionizable medium such as a gas or vapor. It is, of course, apparent that other types of electric discharge devices may be employed. When the type of electric discharge device requires a time delay for cathode heating before the device may be rendered conductive without impairing the same, it is of course apparent that suitable time delay means may be employed for imposing this delay in the operation of the device. Furthermore, although the supply circuit 24, 25 has been described as being energized from a source of alternating current, it is apparent that without departing from my invention the circuit may be modified in order to employ a direct current source of supply for energizing the supply circuit.

In view of the several arrangements above disclosed, various other arrangements will occur to those skilled in the art for selectively applying to the control element of an electric discharge device a plurality of control voltages in order to selectively adjust its timing characteristics.

While I have shown and described my invention as applied to a particular system of connections and as embodying various devices diagrammatically shown, it will be obvious to those skilled in

the art that changes and modifications may be made without departing from my invention, and I therefore aim in the appended claims to cover all such modifications and changes as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. Timing apparatus comprising a supply circuit, an electric discharge device having an anode, a cathode, and a control element, means for selectively applying to the control element of said electric discharge device a plurality of control voltages each of which becomes effective for rendering said electric discharge device conductive a predetermined time after its anode-cathode circuit is connected to said supply circuit, and means responsive to the flow of current through the anode-cathode circuit of said electric discharge device for controlling the operation of said last mentioned means to change the connection of the control element of said electric discharge device from one of said control voltages to another of said control voltages, disconnecting the anode-cathode circuit of said electric discharge device from said supply circuit, and after a predetermined time delay again connecting the anode-cathode circuit to said electric discharge device to said supply circuit.

2. Timing apparatus comprising a supply circuit, an electric discharge device having an anode, a cathode, and a control element, two timing circuits each of which when connected to the control element of said electric discharge device renders it conductive after a predetermined time delay which is different for each timing circuit, transfer means for changing the connection of the control element of said electric discharge device from one of said timing circuits to another of said timing circuits, and means responsive to the flow of current through the anode-cathode circuit of said electric discharge device for controlling the operation of said transfer means and the anode-cathode connection of said electric discharge device with said supply circuit.

3. Timing apparatus comprising a supply circuit, an electric discharge device having an anode, a cathode, and a control element, means for selectively applying to the control element of said electric discharge device a plurality of control voltages each of which becomes effective for rendering said electric discharge device conductive a predetermined time after its anode-cathode circuit is connected to said supply circuit, and means responsive to the flow of current through the anode-cathode circuit of said electric discharge device for operating said last mentioned means to change from one of said control voltages to another of said control voltages.

4. Timing apparatus comprising a supply circuit, an electric discharge device having an anode, a cathode, and a control element, a relay having an operating winding, means for connecting said operating winding in series relation with the anode-cathode circuit of said electric discharge device across said supply circuit, means for selectively applying to the control element of said electric discharge device a plurality of control voltages each of which becomes effective for rendering said electric discharge device conductive a predetermined time after its anode-cathode circuit is connected to said supply circuit, and means responsive to the operation of said relay for operating said last mentioned means to change from one of said control voltages to another of said control voltages.

5. Timing apparatus comprising an electric discharge device having an anode, a cathode, and a control element, means for selectively applying to the control element of said electric discharge device a plurality of control voltages each of which becomes effective after a different timing period for controlling the conductivity of said electric discharge device, means responsive to the conductivity of said electric discharge device for operating said last mentioned means to change from one of said control voltages to another of said control voltages, a supply circuit, and means responsive to the conductivity of said electric discharge device for connecting and reconnecting its anode-cathode circuit to said supply circuit and for disconnecting it from said supply circuit after it has become conductive.

6. Timing apparatus comprising an electric discharge device having an anode, a cathode, and a control element, means for selectively applying to the control element of said electric discharge device a plurality of control voltages each of which becomes effective after a different timing period for controlling the conductivity of said electric discharge device, time delay means for operating said last mentioned means to change from one of said control voltages to another of said control voltages after said electric discharge device has been rendered conductive a predetermined number of times with one of said control voltages applied to its control element, a supply circuit, and means for connecting and reconnecting the anode-cathode circuit of said electric discharge device to said supply circuit and for disconnecting it from said supply circuit after it has become conductive.

7. A timing device circuit comprising a supply circuit, an electric discharge device having an anode, a cathode, and a control element, means for connecting the anode-cathode circuit of said electric discharge device across said supply circuit, means for selectively applying to the control element of said electric discharge device a plurality of control voltages each of which becomes effective for controlling the conductivity of said electric discharge device after a different timing period initiated by completing the connection of the anode-cathode circuit of said electric discharge across said source of supply, and means responsive to the flow of current in the anode-cathode circuit of said electric discharge device for operating said last mentioned means to change from one of said control voltages to another of said control voltages.

8. A timing circuit comprising a supply circuit, an electric discharge device having an anode, a cathode, and a control element, means for connecting the anode-cathode circuit of said electric discharge device across said supply circuit, a relay having an operating winding whose energization is controlled by said electric discharge device, means for selectively applying to the control element of said electric discharge device a plurality of control voltages each of which becomes effective for controlling the conductivity of said electric discharge device after a different timing period initiated by completing the connection of the anode-cathode circuit of said electric discharge across said supply circuit, and means responsive to the operation of said relay for operating said last mentioned means to change from one of said control voltages to another of said control voltages.

9. Timing apparatus comprising a supply circuit, an electric discharge device having an anode,

a cathode, and a control element, means for connecting the anode-cathode circuit of said electric discharge device to said supply circuit, a relay having an operating winding whose energization is controlled by said electric discharge device, means for selectively applying to the control element of said electric discharge device a plurality of control voltages each of which becomes effective for controlling the conductivity of said electric discharge device after a different timing period initiated by connecting of the anode-cathode circuit of said electric discharge device to said supply circuit, and means responsive to the operation of said relay and effective after a predetermined time delay for operating said last mentioned means to change from one of said control voltages to another of said control voltages.

10. In combination, a source of alternating current voltage, an electric discharge device having an anode, a cathode, and a control element, means comprising a capacitance energized from said source through the control-element-cathode circuit of said electric discharge device for impressing on said control element a potential negative with respect to its said cathode and tending to maintain said discharge device non-conductive, means for controlling the magnitude of the negative potential to which said capacitance is charged by said source, a switch connected in series relation with the anode-cathode circuit of said electric discharge device and arranged to effect charging of said capacitance when in the open position and to initiate discharging of said capacitance when in the closed position to render said discharge device conductive a predetermined time after the closure thereof, means for closing said switch, means responsive to the flow of current through the anode-cathode circuit of said electric discharge device for operating said controlling means to change the magnitude of the negative potential of said capacitance, and means for opening said switch and closing it again after said capacitance has obtained its controlling potential determined by said controlling means.

11. In combination, a source of alternating current voltage, a relay having an operating winding, an electric discharge device having an anode, a cathode, and a control element, the anode cathode circuit of said discharge device being connected in series relation with said operating winding to control the energization thereof from said source, means comprising a capacitance energized from said source through the control element-cathode circuit of said electric discharge device for impressing on said control element a potential negative with respect to its said cathode and tending to maintain said discharge device non-conductive, a switch connected in series relation with the anode-cathode circuit of said electric discharge device and being arranged to effect charging of said capacitance when in the open position and to initiate discharging of said capacitance when in the closed position to render said discharge device conductive a predetermined time after the closure thereof, and means responsive to the operation of said relay for controlling the connection of said capacitance with said source and the magnitude of its negative potential.

12. In combination, a source of alternating current voltage, an electric discharge device having an anode, a cathode, and a control element, a relay having an operating winding whose energization is controlled by said electric discharge device, means comprising a capacitance energized from said source through the control-element-

cathode circuit of said electric discharge device for impressing on said control element a negative potential with respect to its said cathode tending to maintain said discharge device non-conductive, a switch connected in series relation with the anode-cathode circuit of said electric discharge device and being arranged to effect charging of said capacitance when in the open position and to initiate discharging of said capacitance when in the closed position to render said discharge device conductive a predetermined time after the closure thereof, means for closing said switch, and means responsive to the operation of said relay for opening said switch, changing the connection of said capacitance with said source and the magnitude of its negative potential and after a predetermined time delay again closing said switch.

13. In combination, a source of alternating current voltage, a relay having an operating winding, an electric discharge device having an anode, a cathode, and a control element, the anode-cathode circuit of said discharge device being connected in series relation with said operating coil of said relay to effect energization thereof from said source when in a conducting condition, means tending to maintain said discharge device non-conducting comprising a voltage divider connected across said source and switching means for selectively connecting a capacitance between said control element and different points on said voltage divider, a switch connected in series relation with the operating coil of said relay and the anode-cathode circuit of said discharge device and being arranged to effect charging of said capacitance when in its open position and to initiate discharge of said capacitance when in its closed position to render said discharge device conducting a predetermined time after the closure thereof, means for closing said switch and means responsive to the operation of said relay for opening said switch and for operating said switching means to change the connection of said capacitance from one point to another point on said voltage divider, said capacitance imposing on said control element when connected to one point on said voltage divider a negative voltage tending to maintain said discharge device non-conducting for a predetermined interval of time after the closure of said switch and when connected to another point on said voltage divider, a different negative voltage tending to maintain said discharge device non-conductive for a different predetermined time interval after the closure of said switch.

14. Apparatus comprising a supply circuit, an electric discharge device having an anode, a cathode, and a control element, means for connecting the anode-cathode circuit of said electric discharge device to said supply circuit, two timing circuits each of which when connected to the control element of said electric discharge device renders it conductive after a predetermined time delay which is different for each timing circuit, transfer means for changing the connection of the control element of said electric discharge device from one of said timing circuits to other of said timing circuits, a second electric discharge device having an anode, a cathode, and a control element, means for connecting the anode-cathode circuit of said electric discharge device to said supply circuit, another timing circuit connected to the control element of said second electric discharge device and effective for controlling the conductivity of said second electric discharge device at a time subsequent to that

at which one of said first mentioned timing circuits becomes effective for rendering said first mentioned electric discharge device conductive, means for connecting the anode-cathode circuits of said electric discharge devices to said supply circuit, means responsive to the conduction of current through the anode-cathode circuit of said first mentioned electric discharge device for disconnecting the anode-cathode circuit of said first mentioned electric discharge device from said supply circuit, means responsive to the conduction of current through the anode-cathode circuit of said second electric discharge device for operating said transfer means, means for again connecting the anode-cathode circuit of said first mentioned electric discharge device to said supply circuit after said transfer means has been operated, and means responsive to conduction of current through the anode-cathode circuits of both of said electric discharge devices for disconnecting the anode-cathode circuits of said electric discharge devices from said supply circuit.

15. Apparatus comprising a supply circuit, an electric discharge device having an anode, a cathode, and a control element, means for connecting the anode-cathode circuit of said electric discharge device with said supply circuit, a relay having an operating winding whose energization is controlled by said electric discharge device, switching means for selectively applying to the control element of said electric discharge device a plurality of control voltages each of which becomes effective after a different timing period for controlling the conductivity of said electric discharge device, a second electric discharge device having an anode, a cathode, and a control element, means for connecting the anode-cathode circuit of said second electric discharge device with said supply circuit, a second relay having an operating winding whose energization is controlled by said second electric discharge device, a second switching means for selectively applying to the control element of said second electric discharge device a plurality of control voltages each of which becomes effective after a different time period for controlling the conductivity of said second electric discharge device, and means responsive to the operation of said first mentioned switching means to apply a different control voltage to the control element of said first mentioned electric discharge device, for opening the anode-cathode connection of said first mentioned electric discharge device with said supply circuit and for completing the anode-cathode connection of said second electric discharge device with said supply circuit, and means responsive to the operation of said second relay for operating said second switching means to apply a different control voltage to the control element of said second electric discharge device, for interrupting the anode-cathode connection of said second electric discharge device with said supply circuit and for completing the anode-cathode connection of said first mentioned electric discharge device with said supply circuit.

16. Timing apparatus comprising a supply circuit, an electric discharge device having an anode, a cathode, and a control element, a relay having an operating winding energized by anode-cathode current conduction through said electric discharge device, a plurality of timing circuits each of which when connected to the control element of said electric discharge device becomes effective

tive for controlling the conductivity of said electric discharge device after a different timing period initiated by connecting the anode-cathode circuit of said electric discharge device to said supply circuit, transfer means for changing the connection of the control element of said electric discharge device from one of said timing circuits to another of said timing circuits, a second electric discharge device having an anode, a cathode, and a control element, a second relay having an operating winding energized by anode-cathode current conduction through said second electric discharge device, a timing circuit connected to the control element of said second electric discharge device for controlling the conductivity of said electric discharge device after a time period which is initiated by connecting the anode-cathode circuit of said electric discharge device to said supply circuit and which is longer than the timing period of the one of said first mentioned timing circuits which is first connected to the control element of said first mentioned electric discharge device, means for connecting the anode-cathode circuits of said electric discharge devices to said supply circuit, means responsive to the operation of said first mentioned relay by said first mentioned electric discharge device becoming conductive for disconnecting the anode-cathode circuit of said first mentioned electric discharge device from said supply circuit, means responsive to the operation of said second relay by said second electric discharge device becoming conductive for operating said transfer means to change the connection of the control element of said first mentioned electric discharge device from one of said timing circuits to another of said timing circuits and for maintaining said connection with said other timing circuit so long as said second electric discharge device remains conducting, means for reconnecting the anode-cathode circuit of said first mentioned electric discharge device with said supply circuit and for maintaining the anode-cathode connection of said second electric discharge device with said supply circuit, and means responsive to the operation of said first mentioned relay by said first mentioned electric discharge device again becoming conductive while said second electric discharge device remains conductive for disconnecting the anode-cathode circuits of said electric discharge devices from said supply circuit and thereby deenergizing said relays.

17. Apparatus comprising a supply circuit, an electric discharge device having an anode, a cathode, and a control element, means for connecting the anode-cathode circuit of said electric discharge device with said supply circuit, a relay having an operating winding whose energization is controlled by said electric discharge device, switching means for selectively applying to the control element of said electric discharge device a plurality of control voltages each of which becomes effective after a different timing period for controlling the conductivity of said electric discharge device, a second electric discharge device having an anode, a cathode, and a control element, means for connecting the anode-cathode circuit of said second electric discharge device with said supply circuit, a second relay having an operating winding whose energization is controlled by said second electric discharge device, a second switching means for selectively applying to the control element of said second electric discharge device a plurality of control volt-

ages each of which becomes effective after a different time period for controlling the conductivity of said second electric discharge device, means responsive to the operation of said first mentioned relay for operating said first mentioned switching means to apply a different control voltage to the control element of said first mentioned electric discharge device, for opening the anode-cathode connection of said first mentioned electric discharge device with said supply circuit and for completing the anode-cathode connection of said second electric discharge device with said supply circuit, and means responsive to the operation of said second relay for operating said second switching means to apply a different control voltage to the control element of said second electric discharge device, for interrupting the anode-cathode connection of said second electric discharge device with said supply circuit and for completing the anode-cathode connection of said first mentioned electric discharge device with said supply circuit, a third electric discharge device, means for connecting the anode-cathode circuit of said third electric discharge device with said supply circuit, a third relay having an operating winding whose energization is controlled by said third electric discharge device, means for applying to the control element of said third electric discharge device a control voltage which becomes effective after a predetermined timing period, means responsive to the operation of said second relay for completing the connection of said third electric discharge device with said supply circuit, means responsive to the operation of said third relay for operating said received switching means, and means responsive to the concurrent operation of said second and third relays for operating said first and second switching means, for opening the anode-cathode connection of said second and third electric discharge devices with said supply circuit and for completing the connection of said first electric discharge device with said supply circuit.

18. The combination of an electronic timer including a supply circuit, an electric valve including an anode, a cathode and a control member, means connecting said anode-cathode circuit to said supply circuit, two timing circuits for producing transient control voltages, means connecting one of said timing circuits to control the relative voltage of said cathode and said control member, means for initiating operation of said electronic timer by impressing the transient voltage of said one of said timing circuits on said control member to effect a predetermined change in the conductivity of said electric valve at the end of a predetermined interval, with means responsive to said change in conductivity of said electric valve for transferring energization of said control member to the other of said timing circuits to change the interval between initiation of the operation of said electronic timer and the instant at which the transient voltage impressed on said control member is effective to produce said predetermined change in conductivity of said electric valve, and means for reinitiating the operation of said electronic timer by impressing the transient control voltage of the other of said timing circuits on said control member.

19. The combination of an electronic timer including a supply circuit, an electric valve including an anode, a cathode and a control member, means connecting said anode-cathode circuit to said supply circuit, two timing circuits for pro-

ducing transient control voltages, means connecting one of said timing circuits to control the relative voltage of said cathode and said control member, means for initiating operation of said electronic timer by impressing the transient voltage of said one of said timing circuits on said control member to effect a predetermined change in the conductivity of said electric valve at the end of a predetermined interval, with means responsive to said change in conductivity of said electric valve for transferring energization of said control member to the other of said timing circuits to change the interval between initiation of the operation of said timer and the instant at which the transient voltage impressed on said control member is effective to produce said predetermined change in conductivity of said electric valve, a second timer initiated in operation in response to said predetermined change in conductivity of said electric valve, and means responsive to the operation of said last mentioned timer for reinitiating the operation of said electronic timer with said other timing circuit controlling the voltage of said control member.

20. The combination of an electronic timer including a supply circuit, an electric valve having an anode, a cathode and a control member, means connecting said anode-cathode circuit for energization from said supply circuit, a timing circuit including resistance and a capacitor, means connecting said timing circuit with said control member to energize said control member in accordance with the voltage of said capacitor, and means for initiating operation of said timing circuit to impress a transient control voltage on said control member to effect a predetermined conductivity of said electric valve at the end of a predetermined interval, with means responsive to said predetermined conductivity of said elec-

tric valve for altering said timing circuit to change the interval between initiation of the timing operation of said timer and the instant at which the transient voltage impressed on the control member is effective to produce said predetermined conductivity of said electric valve and additional means operable in response to the predetermined conductivity of said electric valve means for reinitiating the operation of said electronic timer with said timing circuit altered.

21. The combination of an electronic timer including a supply circuit, an electric valve having an anode, a cathode and a control member, means connecting said anode-cathode circuit for energization from said supply circuit, a timing circuit including resistance and a capacitor, means connecting said timing circuit with said control member to energize said control member in accordance with the voltage of said capacitor, and means for initiating operation of said timing circuit to impress a transient control voltage on said control member and to effect a predetermined conductivity of said electric valve at the end of a predetermined interval, with means responsive to said predetermined conductivity of said electric valve for altering said timing circuit to change the interval between initiation of the timing operation of said timer and the instant at which the transient voltage impressed on the control member is effective to produce said predetermined conductivity of said electric valve, a second timer initiated in operation in response to said predetermined conductivity of said electric valve and means responsive to the expiration of the timing interval of said second timer for reinitiating the operation of said electronic timer with said timing circuit altered.

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