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ELECTRICAL TIMING APPARATUS

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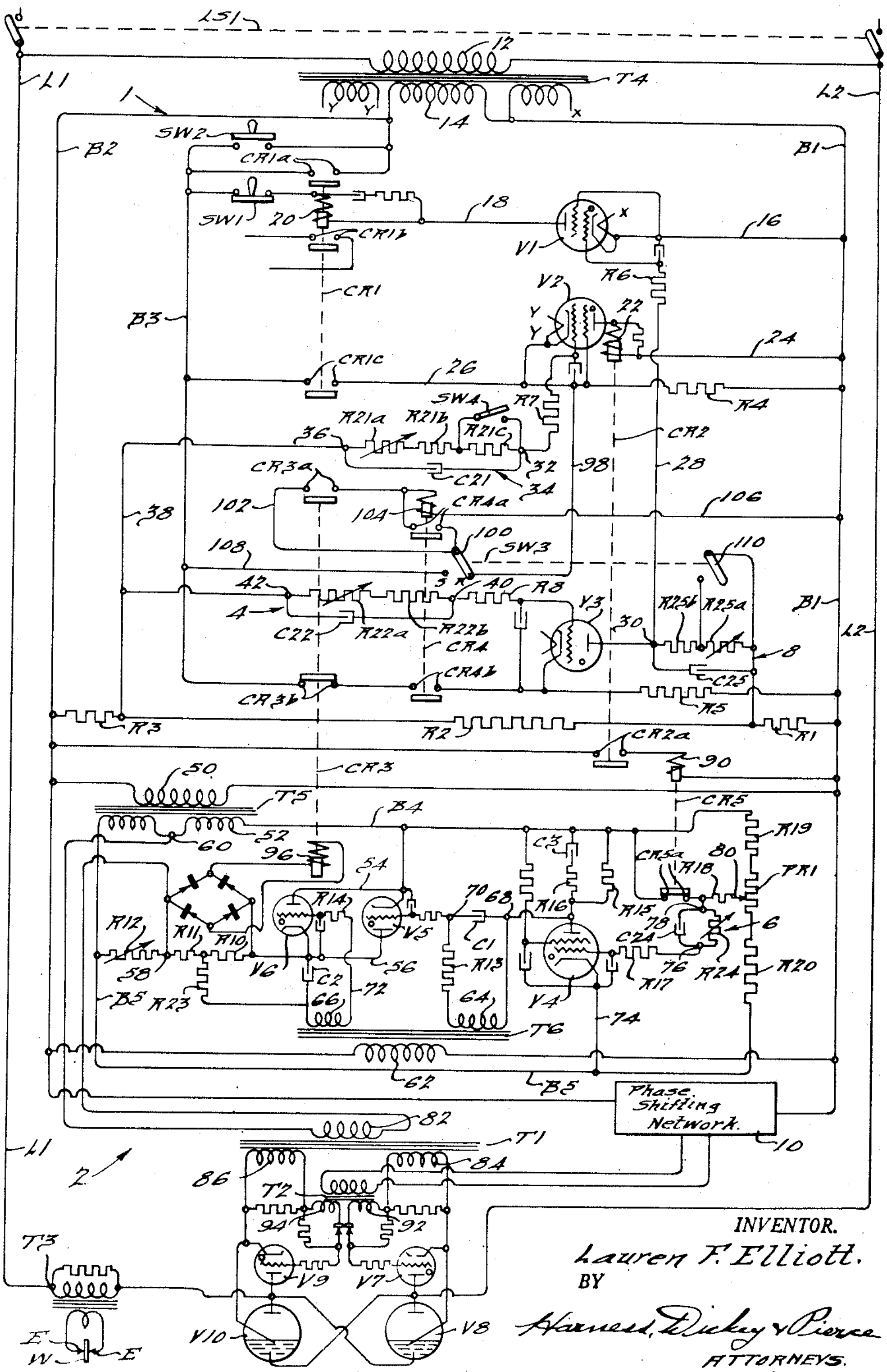

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ELECTRICAL TIMING APPARATUS

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18 Claims. (Cl. 250—27)

This invention relates generally to an electrical timing mechanism which is adapted among other uses for controlling the various operations of a welding mechanism.

An object of the invention is to provide a new apparatus of the character described.

Another object of this invention is to provide such an apparatus which uses a small number of circuit elements such as electric valves.

Another object of this invention is to provide such an apparatus which is economical of manufacture and simple and trouble-free in operation.

A more specific object of this invention is to provide such a network in which a single tube controls two timing operations.

Other objects of this invention will be apparent from the specification, the appended claims and the drawing in which the single figure thereof illustrates diagrammatically an electrical timing apparatus embodying the invention.

The shown control system comprises a sequencing network 1 and a synchronously firing network 2 which is basically that shown and claimed in a copending application of Lloyd C. Poole, Serial No. 135,789, filed December 29, 1949, now Patent No. 2,564,500 issued August 14, 1951, for Electrical Control Apparatus. The sequencing network 1 comprises a plurality of discontinuous control type valves V1, V2 and V3, the valve V1 being arranged so that upon conduction it will energize the relay CR1 for moving the electrodes E, through suitable mechanism, to clamp the work W and to initiate the operation of the valve V2. The valve V2 after a predetermined time interval subsequent to actuation of the relay CR1 will conduct to energize the relay CR2 which will start the synchronizing current controlling network 2. During the period in which it is desired that welding current flow between the electrodes E, the relay CR3 will be energized and the "hold time" network 4 of the sequencing network 1 will remain charged.

At the end of the weld interval as determined by the network 6, the relay CR3 will become de-energized to terminate the charging phase of the network 4 which then begins to time out measuring the "hold time" period. After the network 4 times out, the valve V3 will commence to conduct energizing the "off time" network 8 which will immediately render the valve V1 nonconductive de-energizing the relay CR1 and thereby permitting the mechanism not shown to move the electrodes E away from the work W. During the weld time interval no timing function is being accomplished by the sequencing network 1 all of the timing then being controlled by the synchronous network 2.

This network 2 comprises a plurality of discontinuous control type valves V4 through V10. The valve V4 is normally held conductive to maintain the valve V5 blocked. The valve V6 is connected in back-to-back relation with the valve V5 and will conduct only during subsequent half cycles of voltage to which the valve V5 conducts. When the valves V5 and V6 are conductive they de-energize the transformer T1 removing the blocking bias voltage applied thereby to the valves V7 and V9 so that these valves are controlled in accordance with the voltage supplied between their grid and cathode by the transformer T2 under control of the phase shifting network 10. The network 10 determines the instants during the voltage wave in which the valves V7 and V9 are rendered conductive. Conduction of the valves V7 and V9 render the valves V8 and V10, arranged in back-to-back relationship and in series with the primary winding of the transformer T3, conductive to provide current flow through the welding transformer T3 between the main power supply lines L1 and L2. The valve V7 controls the valve V8 while the valve V9 controls the valve V10 and the valves V8 and V10 are fired each time and at substantially the same instants that the valves V7 and V9 respectively are fired.

Referring in detail to the network 1, a transformer T4 has a primary winding 12, the end terminals of which are connected between the lines L1 and L2. The main secondary winding 14 of this transformer has one terminal connected to a bus B1 and its other terminal connected to a bus B2. A plurality of series connected resistors R1, R2 and R3 are connected between the busses B1 and B2. The resistors R1 and R3 furnish bias voltages as will be apparent below.

The valve V1 has its cathode connected by conductor 16 to the bus B1 and its anode connected by conductor 18, the energizing winding 20 of the control relay CR1, and a normally closed emergency stop switch SW1 to a bus B3. The bus B3 may be connected to the transformer T4 and bus B2 by closure of a normally open pilot switch SW2 or by closure of the contacts CR1a of the relay CR1. The anode of the valve V2 is connected through the energizing winding 22 of the relay CR2 and conductor 24 to the bus B1. The cathode of this valve is connected to the bus B1 through a resistor R4. The cathode is also connectible with the bus B3 through contacts CR1c of the relay CR1. The anode of the valve V3 is connected through the "off time" impedance network 8 and resistor R1 to the bus B1. The cathode of this valve is connected directly to the bus B1 through a resistor R5 and selectively connectible to the bus B3 through the series arranged contacts CR3b of the relay CR3 and contacts CR4b of the relay CR4.

The grid of the valve V1 is connected through the usual grid current controlling resistor R6 and conductor 28 to the terminal 30 of the "off time" network 8. This terminal 30 is also connected to the anode of the valve V3. Therefore the potential appearing across the network 8 is applied as a bias potential between the grid and cathode of the valve V1. The grid of the valve V2 is connected through a grid current controlling resistor R7 to one terminal 32 of a "squeeze time" network 34, the other terminal 36 of which being connected by conductor 38 to the common connection between the resistors R2 and R3 so that upon closure of the switch SW2 or contacts CR1a and contacts CR1c, the bias potential appearing across the network 34 will be applied as a blocking bias potential between the grid and cathode of the valve V2. The grid of the valve V3 is connected through a grid current limiting resistor R8 to one terminal 40 of the hold time network 4, the other terminal 42 of which being connected to the bus 38. Upon closure of the switch SW2 or contacts CR1a and closure of the contacts CR3b and CR4b, the potential appearing across the network 4 will appear as a blocking bias potential between the grid and cathode of the valve V3.

Referring to the network 2, the anode voltage for the valves V4, V5 and V6 is supplied by a transformer T5 having its primary winding 50 connected between the busses B1 and B2. The transformer T5 is provided with a center tapped secondary winding 52. One end terminal of the winding 52 is connected to bus B4 and the other end terminal is connected with bus B5. The cathode of the valve V5 and the anode of the valve V6 are connected together and to the bus B4 by a conductor 54. The anode of the valve V5 and cathode of the valve V6 are connected together by conductor 56 and through series connected resistors R10, R11 and R12 to the bus B5. One or more of the resistors R10, R11 and R12 may be adjustable in magnitude and, as shown, R12 is adjustable. The total value of the resistance of the resistors R10 and R11 should approximate the value of the resistance of the resistor R12 so that when current is flowing through the valves V5 and V6 between the busses B4 and B5, the potential of the common connection 58 between the resistors R11 and R12 will be substantially at the same potential as the center tap 60 of the winding 52 for a purpose which will be made clear below.

A transformer T6 has its primary winding 62 connected between the busses B1 and B2 and is provided with a pair of secondary windings 64 and 66. One terminal of the winding 64 is connected to one terminal 68 of a capacitor C1, the other terminal 70 of which is connected through a resistor R13 to the other terminal of the winding 64. One terminal of the winding 66 is connected by conductor 72 and grid current limiting resistor R14 to the grid of the valve V6. The cathode of the valve V6 is connected through a capacitor C2 to the opposite terminal of the winding 66.

The polarity of the potential produced by the winding 64 is arranged 180° out of phase with the voltage appearing between the anode and cathode of the valve V5 and is phase shifted into a position in which it lags this anode to cathode voltage of the valve V5 by a few electrical degrees as, for example, in the neighborhood of 10 to 25 degrees. By so arranging the polarity of this winding 64 and the resultant potential appearing across the capacitor C1, the valve V5 will be held nonconductive during all except the initial 10 to 25 degrees of the voltage wave appearing thereacross. The polarity of the winding 66 is similarly arranged with respect to the voltage appearing between the anode and cathode of the valve V6 and it is likewise phase shifted, lagging 10 to 25 degrees by means of the capacitor C2.

The normally conductive valve V4 has its anode connected through a resistor R15 to the bus B4 and through a resistor R16 connected in series with a capacitor C3 to the bus B4, the resistor R15 being in parallel relationship with the series connected resistor R16 and capacitor C3. The cathode of the valve V4 is connected by conductor 74 to the bus B5. The terminal 68 of the capacitor C1 is connected intermediate the resistor R16 and the anode of the valve V4. Since the cathode of the valve V5 is connected with the bus B4 and the anode of the valve V4 is connected with the bus B4, the voltage drop between the anode of the valve V4 and bus B4 is superimposed on the alternating voltage supplied by the capacitor C1 and maintains the valve V5 blocked.

The grid of the valve V4 is connected through a grid current limiting resistor R17 to one terminal 76 of the network 6. The other terminal 78 of this network is connected through the normally closed contacts CR5a of relay CR5 to the bus B4. The terminal 78 is also connected through a resistor R18 to a movable contact 80 of a potentiometer resistor PR1. One end of the resistance winding of the potentiometer resistor PR1 is connected through a resistor R19 to the bus B4. The other terminal is connected through a resistor R20 to the bus B5. Therefore when the contacts CR5a are closed, the potential of the terminal 78 will be that of the bus B4. When the contacts CR5a are in open circuit position, the potential of the terminal 78 will be intermediate that of the busses B4 and B5 as determined by the adjusted position of the arm 80. When the contacts CR5a of the relay CR5 are closed and the capacitor C24 has reached equilibrium conditions, the potential appearing between terminal 78 and the grid of valve V4 is substantially equal to the potential between the busses B4 and B5. Therefore when the contacts CR5a are opened and the potential of the terminal 78 is lowered to that of the contact 80, the potential of the grid will be lowered below that of the cathode of valve V4, and the valve V4 will become nonconductive. The capacitor C24 will then commence to discharge through the resistor R24 gradually raising the potential of the grid of valve V4 until after a predetermined time, as determined by the resistor R24, the valve V4 will again conduct. The opening of contacts CR5a therefore initiates a limited conductive period of valve V4. The reclosure of contacts CR5a merely further increases the potential of the grid relative to the cathode and has no effect on the conductivity of valve V4 but does however recharge the capacitor C24 so that reopening of contacts CR5*a* will establish a new conducting period of valve V4.

It is believed that the remainder of the details of construction of this network may best be understood from a description of operation which is as follows:

The network is prepared for operation by closure of the switch LS1 which acts to connect the lines L1 and L2 to a suitable source of alternating current energy supply. Energization of the lines L1 and L2 immediately energizes the transformer T4 which establishes an alternating potential between the busses B1 and B2. At this time, the switch SW2 and the contacts CR1*a* of the relay CR1 will be in open position and the bus B3 will not be connected with the bus B2. Therefore the anode circuits of the valve V1, V2 and V3 will be interrupted. Energization of the busses B1 and B2 does, however, cause a flow of current from the bus B1 through the resistor R3, conductor 38, network 34, resistor R7, grid to cathode in the valve V2 and through the resistor R4 to the bus B1. This grid rectified current acts to establish a charge across the capacitor C21 of the network 34. Grid current also flows from the bus B2 through the resistor R3, network 4, grid to cathode in the valve V3, and through resistor R4 to bus B1. This rectified grid current flow acts to establish a charge across the capacitor C22 of the network 4.

Energization of the busses B1 and B2 also energizes the primary winding 50 of the transformer T5 whereby the secondary winding 52 thereof will apply an alternating potential between the busses B4 and B5. At this time the relay CR5 will be de-energized and its contacts CR5*a* will be closed connecting the terminal 78 to the bus B4. The valve V4 will conduct and the capacitor C3 will be rapidly charged. Conduction between the anode and cathode of the valve V4 causes current to flow from the bus B4 through the resistor R15, valve V4 and conductor 74 to the bus B5 to establish a voltage potential across the resistor R15 and to charge the capacitor C3 at a rate determined by the value of the resistor R16. This potential across the resistor R15 is combined with the alternating potential appearing across the capacitor C1 due to energization of the transformer T6, primary winding 62 of which is connected between the busses B1 and B2, and the combined potential will maintain the grid to cathode bias voltage of the valve V5 at a value to maintain the valve V5 blocked.

As will be explained subsequently, unless the valve V5 conducts, no potential will be established across the resistors R10 and R23 and the valve V6 will be held nonconductive by the voltage supplied by the winding 66. Since the valves V5 and V6 are not conductive, the potential of the terminal 58 is not the same as that of the center tap 60 and the transformer T5 energizes the primary winding 82 of the transformer T1. The secondary windings 84 and 86 of the transformer T1 are therefore energized to apply a blocking voltage between the grids and cathodes of the valves V7 and V9 whereby the valves V8 and V10 are not fired.

When it is desired to initiate a sequence of operation of the welding machine, the pilot switch SW2 is momentarily closed to connect the bus B3 to the bus B2. Upon energization of the bus B3, current will flow therefrom through the winding 20 of the relay CR1, conductor 18, valve V1 and conductor 16 to the bus B1. Energization of the relay CR1 closes its contacts CR1*a*, CR1*b* and CR1*c*. Closure of the contacts CR1*a* establishes a holding circuit around the switch SW2 which may now be opened without interfering with the sequence of operation then in progress. Closure of the contacts CR1*b* completes an energizing circuit for causing the electrodes E to be moved against the work W. Since such circuit and mechanism for moving the electrodes is well known to those skilled in the art, it has not been illustrated in the interests of simplicity. At the same time closure of contact CR1*c* completes the circuit for connecting the terminal 36 of the network 34 to the cathode of the valve V2 so that the potential appearing across the network 34 will be applied as a blocking bias voltage between the grid and cathode of this valve V2. The circuit for connecting the terminal 36 with the cathode extends from the terminal 36 through conductor 38, resistor R3, bus B2, closed contacts CR1*a*, bus B3, closed contacts CR1*c* and conductor 26.

Closure of the contacts CR1*c* shifts the potential of the cathode of the valve V2 from substantially that of the bus B1 to that of the bus B3 and terminates any further flow of charging current to the capacitor C21 of the network 34. Upon termination of the charging current flow to the network 34, the capacitor C21 thereof commences to discharge through the resistors R21*a*, R21*b*, and R21*c*. After a predetermined time, the charge on the capacitor C21 and subsequently that of the network 34 will decrease sufficiently so that the positive bias potential furnished by the resistor R3 causes the valve V2 to conduct.

Conduction of the valve V2 establishes a circuit from the bus B1 through conductor 24, winding 22, valve V2, conductor 26 and the contacts CR1*c* to the bus B3 energizing the relay CR2 closing its contacts CR2*a* thereof. Closure of the contacts CR2*a* energizes the winding 90 of the control relay CR5 which opens its contacts CR5*a*. Opening of the contacts CR5*a* lowers the potential of the terminal 78 consequently lowering the potential of the grid of the valve V4 with respect to the cathode thereof so that conduction of the valve V4 is terminated.

Very quickly the charge on the capacitor C3 is dissipated through the resistors R15 and R16 eliminating the blocking bias voltage provided thereby and permitting the voltage provided by winding 64, acting through the resistor R13 and capacitor C1, to initiate conduction of the valve V5 at an early point in the next cycle of voltage in which the anode of this valve is positive with respect to the cathode.

Conduction of the valve V5 closes a circuit from the bus B5 through resistors R10, R11 and R12, the conductor 56, valve V5, and conductor 54 to the bus B4. Energization of the resistors R10, R11 and R12 shifts the potential of the terminal 58 to the same potential as that of the center tap 60 de-energizing the transformer T1 and eliminating the blocking bias voltage supplied by its windings 84 and 86 to the firing valves V7 and V9. At the proper point on this same voltage wave as determined by the phase shifting network 10, a pulse of voltage will be supplied by the winding 92 of the transformer T2 to cause valve V7 to conduct. Conduction of the valve V7 closes the circuit for the igniter of the valve V8 whereby the valve V8 is rendered conductive to supply current from the line L2 through the transformer T3 to the line L1 causing a voltage to be induced in its secondary winding to provide a flow of current through the work W between the electrodes E.

The flow of current through the resistor R10 sets up a voltage across the circuit comprising the resistors R10 and R23 and condenser C2 which changes the phase of the voltage supplied by the winding 66 between the grid and cathode of the valve V6 making the grid to cathode bias voltage lagging with respect to the 180° out of phase normal connection of the winding 66 whereby the valve V6 will conduct during the subsequent half cycle to the half cycle in which the valve V5 conducted to cause the valve V10 to conduct in a manner similar to the valve V8 but during the half cycle subsequent to the half cycle in which the valve V8 conducted. The valves V5 and V6 will continue to conduct during the time interval in which valve V4 remains blocked and maintain the valves V8 and V10 conductive.

At the time that the valves V5 and V6 started to conduct a voltage was established across the resistors R10 and R11 which is applied through the full wave rectifying network to the winding 96 of the relay CR3 to cause this relay to close its contacts CR3*a* and to open its contacts CR3*b* and to remain in its energized condition as long as the valves V5 and V6 conduct. Preferably the relay contacts CR3*b* open before contacts CR3*a* close to insure that the relay contacts CR4*b* will not close before contacts CR3*b* open. Closure of the contacts CR3*a* completed a circuit from the bus B3 through the closed contacts CR1*c*, conductor 26, a conductor 98, an arm 100 of the single repeat switch SW3, conductor 102, contacts CR3*a*, winding 104 of the relay CR4 and a conductor 106 to the bus B1.

Upon energization, the relay CR4 closes its contacts CR4*a* and CR4*b*. Closure of the contacts CR4*a* establishes a by-pass circuit about the contacts CR3*a* to form a holding circuit for maintaining the relay CR4 energized even though the contacts CR3*a* may subsequently open. Closure of the contacts CR4*b* does not occur until after the contacts CR3*b* are opened and the circuit between the bus B3 and the cathode of the valve V3 remains open. This interchange of the condition of the contacts CR3*b* and CR4*b* is without effect except to prepare the circuit for the rendering of the valve V3 conductive at a subsequent time.

The network 6 determines the time interval in which welding current may flow between the electrodes E. At the time that the relay CR5 is energized opening its contacts CR5*a*, the capacitor C24 is charged to substantially the potential between busses B4 and B5. The capacitor C24 now being charged to a potential greater than that between the contact 80 and bus B5 will start discharging through the resistor R24. The value of the resistance of the resistor R24 determines the time required to discharge the capacitor to a potential to permit reconduction of valve V4 which is the weld time interval. At the end of such interval and reconduction of the valve V4, a potential drop is re-established across the resistor R15 and the series connected capacitor C3 and resistor R16 connected in parallel therewith to re-establish the blocking bias voltage between the grid and cathode of the valve V5. If this occurs during a half cycle in which the valve V5 is not conducting, the valve V5 will remain nonconductive and the weld interval will end with the end of the half cycle in which valve V6 is conducting. If, however, this occurs after the valve V5 commenced to conduct, the valve V5 will complete its conducting half cycle and the valve V6 will also conduct the subsequent half cycle at the end of which time the valve V5 will not conduct again and the valve V6 being a trailing valve will not conduct.

Termination of the conduction of the valves V5 and V6 causes the terminal 58 to assume a potential different from that of the center tap 60 re-energizing the blocking transformer T1 which blocks the valves V7 and V9 to prevent further conduction of the valves V8 and V10. Also termination of the conduction of the valves V5 and V6 and the termination of the potential drop across resistors R10 and R11 de-energizes the winding 96 of the relay CR3 which then opens its contacts CR3*a* without effect (due to the now closed contacts CR4*a*) and closes its contacts CR3*b*. Closure of the contacts CR3*b* changes the potential of the cathode of the valve V3 from approximately that of the bus B1 to that of the bus B2. This terminates further charging current flow to the capacitor C22 of the network 4 which then commences to discharge through the resistors R22*a* and R22*b*. At the end of a predetermined "hold time" period as determined by the setting of the variable resistor R22*a*, the charge across the network 4 will have decreased sufficiently so that the conducting bias voltage applied by the resistor R3 will cause the valve V3 to conduct.

Conduction of the valve V3 establishes a circuit from the bus B1 through the resistor R1, network 8, valve V3, closed contacts CR4*b* and CR3*b* to the bus B3 to provide a potential drop across the network 8. The drop across the network 8 is opposite in polarity to that across the resistor R1 and is of sufficient magnitude to place a blocking bias potential between the grid and cathode of the valve V1 which thereupon terminates its conductive period.

Termination of conduction of the valve V1 de-energizes the winding 20 of the relay CR1 which then opens its contacts CR1*a*, CR1*b* and CR1*c*. The result of opening of the contacts CR1*a* depends somewhat on the condition of the switch SW2. If this switch SW2 has previously been opened, opening of the contacts CR1*a* will de-energize the bus 3 and subsequent to the discharging time of the "off time" network 8, the networks 1 and 2 will assume their initial conditions. If, however, the switch SW2 has been maintained closed the bus B3 will still be maintained energized and subsequent to the timing out of the "off time" network 8, as will be presently described, the networks 1 and 2 will start through another operative cycle. Opening of the contacts CR1*b* de-energizes the circuit therethrough controlling the movement of the electrodes E against the work W which electrodes E then move away from the work W permitting the work to be moved to another position for a subsequent welding operation. Opening of the contacts CR1*c* breaks the circuit through the conductor 26 terminating further conduction through the valve V2 de-energizing the winding 22 of the relay CR2 which then opens its contacts CR2*a*.

Opening of the contacts CR2*a* de-energizes the winding 90 of the relay CR5 to close its contacts CR5*a* which upon closure raise the potential of the terminal 78 of the network 6 to that of the bus B4 whereby the capacitor C24 of the network 6 will assume a charge which is substantially equal to the difference in potential between the busses B4 and B5 to prepare the network 6 for timing a subsequent weld interval.

Opening of the contacts CR1*c* also breaks the circuit through the winding 104 of the relay CR4 permitting its contacts CR4a and CR4b to open. Opening of the contacts CR4a breaks the holding circuit for the relay CR4 whereby it will not be re-energized until a subsequent closure of the contacts CR3a. Opening of the contacts CR4b causes the cathode of the valve V3 to assume a potential approximating that of the bus B1 to permit a grid conduction of the valve V3 for re-charging the "hold time" network 4, and also terminates the flow of current through the valve V3. Capacitor C25 then commences to discharge through resistors R25a and R25b.

The above described functions, occurring as a consequence of the rendering of the valve V1 blocked by the "off time" network 8, occur very rapidly. Subsequently the capacitor C25 will discharge through the resistors R25a and R25b sufficiently to permit conducting bias voltage to be applied by the resistor R1 between the grid and cathode of the valve V1. This time interval between blocking of the valve V1 and its reconduction due to discharge of the capacitor C25 through the resistors R25a and R25b, or in other words timing out of the network 8, determines the "off time" period of the welding apparatus and provides time for moving the workpiece from one weld spot which has been welded into a position for the welding of a subsequent spot. Assuming, as stated above, the switch SW2 has remained closed, a subsequent welding cycle will be accomplished by a repeat operation of the networks 1 and 2 as described above.

If now the single repeat switch SW3 is moved from its "R" position as shown to its "S" or single weld position, the arm 100 thereof will be moved out of engagement with the contacts connected to conductor 98 and moved into engagement with its other contacts to complete a circuit from the conductor 108 to the bus B3. In this position the opening of the contacts CR1c will not break the circuit through the winding 104 and the relay CR4 will be maintained in its energized position with its contacts CR4a and CR4b closed. Under these conditions, the valve V3 will remain conductive maintaining a potential across the network 8 and the valve V1 continually blocked. As long as the valve V1 is blocked, a subsequent welding cycle cannot be performed by the networks 1 and 2. A subsequent welding cycle is performed by opening the switch SW2 which terminates conduction through valve V3 to permit the network 8 to de-energize and also de-energizes relay CR4 to permit it to reset to its normal position. In order to eliminate a substantial portion of the timing out of the "off time" network 8, the switch SW3 is provided with a second arm 110 which in the repeat or "R" position opens a shunting circuit around the resistor R25a and in the single or "S" position closes such shunting circuit. The effect of this shunting circuit is to decrease the discharge time of the capacitor C25 to reduce the "off time" period of the network 1.

A switch SW4 may be provided in shunt with the resistor R21c and which, when closed, will decrease the range of time which may be provided for discharge of the capacitor C21 due to adjustment of the value of the resistor R21a. The use of multiple resistors for discharge of the capacitors of the various networks is desirable since they limit the degree of adjustment afforded by the variable resistors. If, for any reason, it is desired to have one or more of the shown fixed resistors be made adjustable or to eliminate these fixed resistors and use solely one type of resistor, either fixed or adjustable, such construction comes within the scope of the present disclosure.

What is claimed and is desired to be secured by United States Letters Patent is as follows:

1. In an electronic timing apparatus, a pair of terminals, a pair of time delay impedance networks, each said network comprising a chargeable energy storage device and a discharging circuit therefor, an electric valve having a pair of main electrodes and a control electrode, means including one of said networks connecting one of said main electrodes to one of said terminals, an impedance element, means including said element connecting the other of said main electrodes to said one terminal, means including another of said networks connecting said control electrode to the other of said terminals, means including a switch connecting said other main electrode to said other terminal, and means responsive to a charged condition of said one network for causing said switch to open.

2. In an electronic timing apparatus for controlling a plurality of operations, a pair of supply terminals, a pair of time delay impedance networks, each said network comprising a chargeable energy storage device and a discharging circuit therefor, an electric valve having a pair of main electrodes and a control electrode, means including one of said networks connecting one of said main electrodes to one of said terminals, an impedance element, means including said element connecting the other of said main electrodes to said one terminal, means including another of said networks connecting said control electrode to the other of said terminals, a normally open and a normally closed switch arranged in series, means including said switches connecting said other main electrode to said other terminal, means for rendering said normally closed switch in open position, means actuated as a consequence of the actuation of said rendering means for actuating said normally open switch to closed position, and means responsive to an energized condition of said one network to render said normally open switch in open position.

3. In a sequencing network, a pair of electrical supply conductors, a third conductor, switching means for connecting said third conductor to one of said pair of conductors, an electric valve having a pair of main electrodes and a control electrode, means including an energy storage impedance network connecting one of said main electrodes to the other of said pair of conductors, means including an impedance element connecting the other of said main electrodes to said other conductor, means including an energy storage impedance network connecting said control electrode to said one conductor, means for actuating said switching means, means including a second switching means connecting said other electrode to said third conductor, and means actuated as a consequence of the connecting of said one and said third conductors together by said first-named switching means for actuating said second-named switching means to connect said other electrode to said third conductor, and means actuated as a consequence of the energization of said first-named storage network to render said first-named switching means in a position to disconnect said third conductor from said one conductor.

4. In a sequencing network, a pair of electrical supply conductors, a third conductor, switching means for connecting said third conductor to one of said pair of conductors, an electric valve hav-

ing a pair of main electrodes and a control electrode, means including an energy storage impedance network connecting one of said main electrodes to the other of said pair of conductors, means including an impedance element connecting the other of said main electrodes to said other conductor, means including an energy storage impedance network connecting said control electrode to said one conductor, means for actuating said switching means, means including a second and a third switch connecting said other electrode to said third conductor, and means actuated as a consequence of the connecting of said one and said third conductors together by said first-named switching means for actuating said second switch to an open position, means operable as a consequence of the actuation of said second switch actuating means for actuating said third switch to a closed position, means rendered effective subsequent to the actuation of said third switch to closed position for placing said second switch in closed position to connect said other electrode to said third conductor, and means actuated as a function of the energization of said first-named storage network to render said first-named switching means in a position to disconnect said third conductor from said one conductor.

5. In a sequencing network, a pair of electrical conductors, a third conductor, switching means for connecting said third conductor to one of said pair of conductors, an electric valve having a pair of main electrodes and a control electrode, means including an energy storage impedance network connecting one of said main electrodes to the other of said pair of conductors, current conducting means for selectively determining the potential of said other electrode whereby it may be maintained substantially at the potential of said other conductor or at that of said third conductor and normally effective to maintain said other electrode at substantially the potential of said other conductor, means including an energy storage impedance network connecting said control electrode to said one conductor, means for actuating said switching means, and means actuated as a consequence of the connecting of said one and said third conductors together by said first-named switching means for actuating said current conducting means to establish the potential of said other electrode at substantially that of said third conductor, and means actuated as a function of the energization of said first-named storage network to render said first-named switching means in a position to disconnect said third conductor from said one conductor.

6. In an electrical timing network, a plurality of sequentially operative circuits individually controlling a plurality of sequentially occurring operating steps, selectively operated means for establishing a sequential operation of said circuits, one of said circuits including an electric valve having a pair of principal electrodes and a control electrode, a pair of current conducting busses, means including a first impedance network connecting one of said principal electrodes to one of said busses, means including a second impedance element connecting the other of said principal electrodes to said one bus, means including a third impedance network connecting said control electrode to the other of said busses, means including a pair of switches connecting said other electrode to said other bus, a first actuator controlling the first of said switches, a second actuator controlling the second of said switches, means responsive to an operative condition of a second of said circuits for actuating said first actuator to move said first switch to open position, means operable as a consequence of the actuation of said first actuator to actuate said second actuator to move said second switch to closed position, means operable as a consequence of said actuation of said second actuator for maintaining said second switch closed, and means operable as a consequence of conduction of said valve for returning said second switch to its open position.

7. In an electrical timing network for controlling a plurality of sequential operations, a first means for controlling one of such operations, a second means actuated as a consequence of the actuation of said first means for initiating a second of such operations, an electric valve having a pair of principal electrodes and a control electrode, a first impedance network connected in series with said principal electrodes, a second impedance network having one terminal thereof connected to said control electrode, switch means for connecting another terminal of said second network to one of said principal electrodes, a third means controlling the time period of such second operation, a fourth means rendered effective at the termination of said third means time period to actuate said switch means to connect said other network terminal to said one principal electrode, and means interconnecting said first network and said first means for terminating such first operation.

8. In an electrical control system, an electric valve having a pair of main electrodes and a control electrode, a pair of supply terminals, a first and a second impedance network, means including said first network connecting one of said main electrodes to one of said terminals, means including said second network connecting said control electrodes to the other of said terminals, means including an impedance element connecting the other of said main electrodes to said one terminal, a first relay having normally open contacts and normally closed contacts, a second relay having two sets of normally open contacts, means connecting said normally closed contacts and one of said second relay sets of normally open contacts in series between said other main electrode and said other terminal, said second relay having an energizing winding, means connecting said first relay normally open contacts in parallel with the other set of contacts of said second relay sets and in series with said winding across said terminals, an actuator for actuating said first relay to open its said normally closed contacts and close its said normally open contacts, said second relay acting upon energization of said winding to close both its said sets of contacts, said normally closed contacts and said second relay one set of contacts being arranged such that said normally closed contacts open prior to closure of said second relay one set of contacts, and means for controlling said first relay actuator.

9. The combination of claim 8 in which a voltage divider is connected between said terminals and one of said networks connecting means includes a portion of said divider.

10. The combination of claim 8 in which a voltage divider is connected between said terminals and said second network connecting means includes a portion of said divider.

11. The combination of claim 10 in which said

first network connecting means includes a portion of said divider.

12. In an electrical timing network, a plurality of sequentially operative circuits individually controlling a plurality of sequentially occurring operating steps, selectively operated means for establishing a sequential operation of said circuits, one of said circuits including an electric valve having a pair of principal electrodes and a control electrode, a pair of current conducting busses, means including a first impedance network connecting one of said principal electrodes to one of said busses, means including a second impedance element connecting the other of said principal electrodes to said one bus, means including a third impedance network connecting said control electrode to the other of said busses, means including a pair of switches connecting said other electrode to said other bus, a first actuator controlling the first of said switches, a second actuator controlling the second of said switches, means responsive to an operative condition of a second of said circuits for actuating said first actuator to move said first switch to open position, means operable as a consequence of the actuation of said first actuator to actuate said second actuator to move said second switch to closed position, and means operable as a consequence of conduction of said valve for returning said second switch to its open position.

13. In an electrical timing circuit, an electric valve having a pair of main electrodes and a control electrode, a first and a second electrical timing network, each said network including a chargeable component and a discharging component for discharging its respective said chargeable component at a controlled rate, said first network being operatively associated with said main electrodes and characterized by the fact that its said chargeable component is charged as a consequence of conduction between said main electrodes, said second network being operatively associated with said control electrode and characterized by the fact that its said chargeable component is charged as a consequence of conduction between said control electrode and one of said main electrodes, means for maintaining a potential difference between said one main electrode and said control electrode to permit conduction therebetween whereby a charge is normally maintained on said chargeable component of said second network, said means being actuatable to discontinue said potential difference and to connect said chargeable component of said second network to supply a bias potential between said one main electrode and said control electrode whereby conduction between said main electrodes is prevented as long as the potential of said second network is above a predetermined value, said means further including structure for applying a potential between said main electrodes, said means further including controlling apparatus actuated by the charge on said chargeable component of said first network, said apparatus being effective when the charge on said just-mentioned component is above a predetermined value to prevent the flow of current between said main electrodes.

14. The combination of claim 13 in which there is provided an initiating device for initiating a sequence of operation of said timing circuit, said structure includes a current controlling device actuatable into a position to render said initiating device ineffective when the charge on said chargeable component is above said predetermined value.

15. In a sequencing network, an electric valve having a pair of main electrodes and a control electrode, a first circuit adapted to be supplied from a source of electrical potential, said first circuit including a first impedance network and a pair of switches and said main electrodes, at least said switches being arranged in series between one of said main electrodes and one side of such potential source, means normally maintaining one of said switches closed and the other of said switches open, a second circuit connected between one side of such source and said control electrode and including a second impedance network, an impedance element connected between said one main electrode and the other side of such source, means for opening said one switch and for closing said other switch, means for thereafter closing said one switch, and means actuatable solely subsequent to the conduction between said main electrodes for opening said other switch.

16. In a sequencing network, an electric valve having a pair of main electrodes and a control electrode, a first circuit adapted to be supplied from a source of potential and including said main electrodes and a first impedance network, a second circuit adapted to be supplied from such source of potential and including a first of said main electrodes and said control electrode and a second impedance network, one of said circuits including a switch movable to a first position to establish a conducting potential between a first of said main electrodes and said control electrode and movable to a second position, said second impedance network being effective to supply a blocking bias potential between said control electrode and one of said main electrodes solely when said switch is in said second position, at least said second impedance network including a chargeable component and a component for discharging said chargeable component, and means effective upon initial movement of said switch to said second position for holding said switch in said second position and releasable solely subsequent to the charging of said first impedance network.

17. A sequence timer for timing at least three functions of a controlled apparatus comprising, a pair of source terminals adapted to be connected to a source of electrical potential, a pair of electric valves, each said valve having an anode and a cathode and a controlling electrode, a first anode circuit connected between said source terminals and including said anode and said cathode of a first of said valves and a current flow responsive device, a first timing network for controlling the first of such functions and having terminals, one of said network terminals being connected to said control electrode of said first valve and the other of said network terminals being connected to one of said source terminals on the cathode side of said circuit, a first normally open switching means in said first circuit intermediate said one source terminal and said cathode of said first valve, a first impedance device connected with said cathode and with the other of said source terminals, a second anode circuit connected between said source terminals and including said anode and said cathode of the second of said valves and a second timing network, a third timing network having terminals, one of said third network terminals being connected to said control electrode of said second valve and the other of said third network terminals being con-

nected to the first of said source terminals on the cathode side of said second circuit, a second normally open switching means in said second circuit intermediate said cathode of said second valve and said first source terminal and normally disconnecting said cathode of said second valve from said first source terminal, a second impedance device connected between said cathode of said second valve and the second of said source terminals, each said timing network comprising a chargeable component and a discharging component therefor, means for closing said first switching means to initiate the timing out of said first network, means actuated in response to current flow through said current responsive device for closing said second switching means to initiate the timing out of said third network, and means responsive to the energization of said second network for thereafter opening said second switching means to initiate the timing out of said second network.

18. A sequence timer for timing at least the Squeeze, Hold, and Off functions of a welding apparatus having movable welding electrodes comprising, a pair of source terminals adapted to be connected to a source of electrical potential, a circuit for controlling the positioning of such electrodes, means for energizing said first circuit, a pair of electric valves, each said valve having an anode and a cathode and a controlling electrode, a first anode circuit including said anode and said cathode of a first of said valves and a current flow responsive device, means responsive to the energization of said electrode controlling circuit for connecting said anode circuit between said source terminals, a Squeeze-time timing network having terminals, one of said network terminals being connected to said control electrode of said first valve and the other of said network terminals being connected to the one of said source terminals on the cathode side of said circuit, a first normally open switching means in said first circuit intermediate said one source terminal and said cathode of said first valve, a first impedance device connected between said cathode and the other of said source terminals, a second anode circuit connected between said source terminals and including said anode and said cathode of the second of said valves and an Off-time timing network, a Hold-time timing network having terminals, one of said Hold-time network terminals being connected to said control electrode of said second valve and the other of said Hold-time network terminals being connected to the first of said source terminals on the cathode side of said second circuit, a second normally open switching means in said second circuit intermediate said cathode of said second valve and said first source terminal and normally disconnecting said cathode of said second valve from said first source terminal, a second impedance device connected between said cathode of said second valve and the second of said source terminals, each said timing network comprising a chargeable component and a discharging component therefor, means for closing said first switching means to initiate the timing out of said Squeeze-time network, means actuated in response to said current responsive device for closing said second switching means to initiate the timing out of said Hold-time network, and means responsive to the energization of said Off-time network for thereafter opening said second switching means to initiate the timing out of said Off-time network and for de-energizing said electrode controlling circuit.

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