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ELECTRICAL CONTROL SYSTEM

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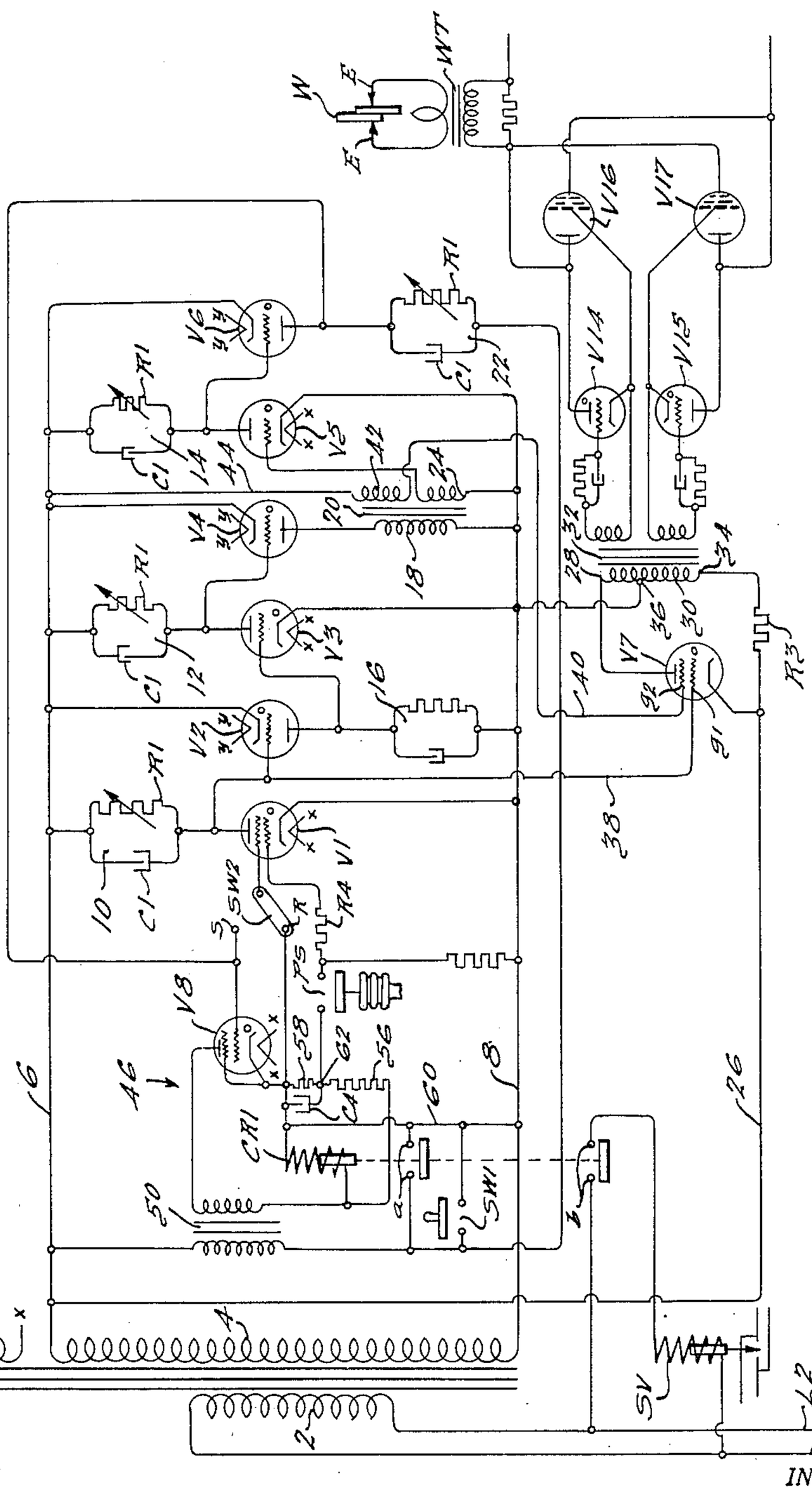

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ELECTRICAL CONTROL SYSTEM

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This invention relates generally to electrical control systems and is particularly adapted among other uses as a timing mechanism for controlling welding apparatus.

The principal objects of the present invention are to provide a control system of the above type which is simple in arrangement, economical of manufacture and which is extremely efficient and accurate in its operation; to provide such a system which utilizes the minimum of parts; and to provide such a system in which successive control valves are arranged oppositely between a pair of electrical conductors.

Other objects of this invention will be apparent from the specification, the appended claims and the drawing, in which the single figure diagrammatically shows the invention as applied to a welding control system.

Generically, the invention contemplates an improved timing device in which a plurality of sequentially arranged electric valves are connected in alternating relation between a single source of alternating potential whereby the potential drop across the working portion of the valve circuit may be utilized to control the next successive valve thereby eliminating the necessity for individual sources of voltage supply for each valve.

Referring to the drawing, the numeral 1 designates a transformer having a primary winding 2 adapted to be supplied from a suitable source of alternating current supply through the line conductors L1 and L2. The secondary winding 4 of the transformer 1 is connected to supply an alternating potential between the busses 6 and 8. Interconnected between the busses 6 and 8 are a plurality of valves V1, V2, V3, V4, V5, and V6. Each of the valves V1 through V6 are the discontinuous control type in which the control bias between the grid or control electrode and cathode controls the time at which the valve becomes conductive but when the valve has once become conductive the control potential between the controlling electrode and the cathode is ineffective to control the conductivity thereof. Valves V1 through V6 are arranged to be actuated sequentially for controlling the "squeeze time," the "weld time," the "hold time" and the "off time" of a resistance welding apparatus.

The anodes of the valves V1, V3 and V5 are each connected to the bus 6 through timing networks 10, 12 and 14. Each of these networks comprises a condenser C1 and a variable resistor R1 connected in parallel with each other. The cathodes of these valves V1, V3 and V5 are directly connected to the bus 8. The cathodes of the valves

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V2, V4 and V6 are directly connected to the bus 6. The anode of the valve V2 is connected through an impedance network 16 to the bus 8. The anode of the valve V4 is connected through the primary winding 18 of a transformer 20 to the bus 8 for a purpose to be described. The anode of the valve V6 is connected through a timing network 22 similar to the networks 10, 12 and 14 to the bus 8 and through either the start switch SW1 or the contacts *a* of the control relay CR1 to the bus 8. In order that the valves V1—V6 may be operated in predetermined timed sequence, the grid of the valve V2 is directly connected to the anode of the valve V1, the grid of the valve V3 to the anode of the valve V2, the grid of valve V4 to the anode of valve V3, the grid of the valve V6 to the anode of the valve V5 and the grid of the valve V5 through one secondary winding 24 of the transformer 20 to the bus 8.

A welding current controlling valve V7 has its cathode directly connected to the bus 6 as by the conductor 26 and its anode connected to one end terminal 28 of a center tapped primary winding 30 of the firing transformer 32. The opposite end terminal 34 of the winding 30 is connected through a resistor R3 to the line 26 while the center tap 36 of the winding 30 is connected to the bus 8. One half of the winding 30 of the transformer 32 is normally energized while the other half is energized only during conduction of the valve V7. The normally energized half applies a blocking bias voltage between the grids and cathode of the welding current control valves V14 and V15 whereby the ignitrons V16 and V17 controlled thereby are held nonconductive. Upon conduction of the valve V7, the current flow through the two halves of the winding 30 cancels each other and the blocking bias on the valves V14 and V15 is removed to permit these valves to render the ignitrons V16 and V17 conductive to energize the welding transformer WT.

The valve V7 is conductive only when the blocking bias is removed from both its control grids. One control grid *g1* of the valve V7 is connected by means of the conductor 38 to the anode of the valve V1. The other grid *g2* of the valve V7 is connected by means of conductor 40 to one terminal of the secondary winding 42 of the transformer 20. The other terminal of this secondary winding 42 is connected to the cathode of valve V7 through the conductor 44, the bus 6 and the conductor 26 whereby the output potential of the winding 42 determines the bias control

voltage between grid *g2* and the cathode of valve V7.

A network 46 controls the bias potential between the control grid and cathode of the valve V1. This network includes a valve V8 having its anode circuit energized from a transformer 50 connected between the busses 6 and 8 through the switch SW1 and contacts *a* of the relay CR1. The anode circuit includes the control winding of the relay CR1 and a pair of series connected resistors 56 and 58 connected in parallel with the relay winding. A capacitor C4 is arranged in parallel with the resistor 58 and the potential thereacross is applied between the cathode and grid of valve V1. The terminal of the capacitor C4 adjacent the cathode of the valve V8 is connected by means of conductor 60 to the bus 8 while the other capacitor terminal is connected through pressure switch PS and resistor R4 to the grid of the valve V1 so that the potential appearing across the capacitor C4 negatively biases the grid with respect to the cathode of the valve V1.

It is believed that the remainder of details of construction may best be understood by reference to the operation of the system which is as follows:

Upon energization of the line conductors L1 and L2, the secondary winding 4 of the transformer places an alternating potential between the busses 6 and 8. Energization of the windings L1 and L2 also energize the heater element for the valves V1 through V8. The connections of these elements to the transformer 1 are conventional and for the sake of simplicity these connections are indicated by *xx* and *yy*. Normally the switch SW1 is open and the control relay CR1 is de-energized so that the valve V8 is nonconductive due to the absence of an anode potential. Consequently there is no potential drop across the capacitor C4 and no blocking bias potential is placed between the grid and cathode of the valve V1. Without such a blocking bias potential, the valve V1 is conductive. Conduction of the valve V1 causes current to flow through the network 10 thereby establishing a potential across the capacitor C1 thereof. This potential established by the capacitor C1 of the network 10 is applied between the grid and cathode of the valve V2 so that the grid thereof is rendered negative with respect to the cathode and the valve V2 is held nonconductive. Since no current is flowing through the valve V2 there is no potential drop established across the network 16 and consequently the valve V3 is conductive and establishes a potential across the capacitor C1 of the network 12. This established potential is applied between the grid and cathode of the valve V4 to block the same. With the valve V4 blocked the transformer 20 is de-energized whereby it is ineffective to apply a blocking potential between the grid and cathode of the valve V5 and the valve V5 will conduct. Conduction of valve V5 establishes a potential drop across the capacitor C1 of the network 14 which potential drop is applied between the grid and cathode of the valve V6 maintaining the valve V6 blocked. Current is also prevented from flowing through the valve V6 due to the open condition of its anode circuit due to the open switch SW1 and the now open contacts *a* of the control relay CR1. The valve V7 will not conduct since the potential of the control grid *g1* with respect to the cathode thereof is maintained negative due to the potential drop appearing across the capacitor C1 of the network 10.

When it is desired to initiate a welding operation, the switch SW1 is momentarily closed energizing the transformer 50 whereby the valve V8 conducts to energize the control relay CR1 and to charge the condenser C4. Energization of the relay CR1 closes its contacts *a* establishing a holding circuit in parallel relation with switch SW1 so that subsequent opening of the switch SW1 will be without effect. Closure of the switch SW1 and/or contacts *a* of relay CR1 will not cause the valve V6 to conduct since the valve V6 is blocked by its grid to cathode bias as described above. Closure of the contacts *b* of the relay CR1 energizes the valve SV whereby the electrodes E are brought into engagement with the work W in the usual manner and also closes the pressure switch PS whereby the potential across the capacitor C4 may be applied to the valve V1.

Charging of the capacitor C4 provides a blocking bias potential between the grid and cathode of the valve V1 blocking this valve. Upon blocking of the valve V1, the capacitor C1 commences to discharge through the variable resistor R1 of the "squeeze time" network 10. At the expiration of a predetermined "squeeze time" interval, the potential across the network 10 will have decreased sufficiently to permit the valve V2 to conduct.

The potential across the network 10 is also applied between the grid *g1* and cathode of valve V7. Since there is no blocking potential between grid *g2* and cathode of the valve V7, V7 will conduct substantially simultaneously with valve V2. Conduction of valve V7 permits a current to flow in the upper half of the winding 30 of transformer 32 to neutralize the effect of the current flowing through the lower half thereof. This effectively de-energizes the transformer 32 to remove the blocking bias on valve V14 and V15 permitting them to fire the ignitrons V16 and V17 to cause welding current to flow to the transformer WT. The value of the resistor R3 is chosen so that it balances the effective resistance of the valve V7. Conduction of the valve V2 establishes a potential across the network 16 which provides a negative grid to cathode blocking potential for the valve V3. Blocking of the valve V3 initiates a discharge of the capacitor C1 of the network 12 which measures the "weld time."

After the predetermined "weld time" interval, as determined by the characteristics of the capacitor C1 and resistor R1 of the network 12, the negative grid to cathode blocking bias is removed permitting the valve V4 to conduct. Conduction of the valve V4 energizes the transformer 20. The secondary winding 24 of the transformer 20 is so polarized upon energization that a negative grid to cathode blocking bias voltage is placed between the grid and cathode of the valve V5. The secondary winding 42 is also so polarized that when the transformer 20 is energized, the winding 42 places a negative blocking bias between grid *g2* and cathode of the valve V7. Blocking of the valve V7 re-energizes the transformer 32 to again place blocking bias potentials on the valves V14 and V15 to terminate the flow of welding current.

Blocking of the valve V5 initiates the discharge of the capacitor C1 of the network 14 and after a predetermined "hold time," the voltage potential thereacross will have reduced sufficiently

to permit the valve V6 to conduct. This "hold time" interval is sufficient to permit the welded joint to cool somewhat. Conduction of the valve V6 establishes a bias potential across the capacitor C1 of the network 22 which potential is applied between the grid and cathode of the valve V8 rendering the valve V8 nonconductive or blocked. Blocking of the valve V8 de-energizes the relay CR1 permitting its contacts *a* and *b* to open. Opening of contacts *b* de-energizes SV permitting the electrodes E to retract from the work W. If, during this operation, the switch SW1 has been opened, the opening of contacts *a* of relay CR1 de-energizes the transformer 52 for terminating the welding operation.

If, on the other hand, the switch SW1 is still closed and the "single-repeat" switch SW2 is in the R or repeat position, the valve V8 will be held blocked for a predetermined "off time" as determined by the discharge characteristics of the network 22. Blocking of the valve V8 permits the capacitor C4 to discharge through the resistor 58 removing the blocking bias from the valve V1 whereby the valve V1 commences to conduct and establishes potential across the capacitor C1 of the network 10 which places a blocking bias on the valve V2. Blocking of the valve V2 permits the network 16 to de-energize and remove the blocking bias on the valve V3 whereby the network 12 is energized to place a blocking bias on the valve V4. Blocking of the valve V4 removes the bias from the valve V5 which conducts to establish a potential across the network 14 which blocks the valve V6. Blocking of the valve V6 initiates the discharge operation of the capacitor C1 of the network 22 which after a predetermined timed interval will decrease sufficiently to remove the blocking bias between the grid and cathode of the valve V8 to permit a subsequent conduction of the valve V8 and a subsequent welding cycle.

With the single repeat switch SW2 in the single or S position, the potential across the network 22 is applied between the screen grid and cathode of the valve V1 to hold the valve V1 blocked. This blocking potential will be maintained as long as the anode circuit of the valve V6 is maintained through the switch SW1 and a repeat welding cycle is prevented. To establish a new welding cycle, the switch SW1 is opened and maintained opened for a sufficient time to enable the network 22 to discharge for removing the blocking bias between the screen grid and cathode of valve V1 whereby the valves V1—V6 will be returned to their initial conditions. A subsequent closure of the switch SW1 will then initiate a new welding cycle as described above.

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

1. In an electrical timing network, a pair of electrical conductors adapted to be supplied with an alternating potential, a plurality of electric valves arranged for sequential operation, each said valve having an anode and a cathode and a control electrode, and being of the discontinuous control type in which a control potential between said control electrode and said cathode controls the time at which said valve becomes conductive but which control potential is ineffective to control the magnitude of such conduction, alternate ones of said valves having their said anodes electrically connected to one of said conductors through impedance networks and having their said cathodes connected to the other of said conductors, intermediate ones of said

valves having their said anodes electrically connected to said other conductor through impedance networks and having their said cathodes connected to said one conductor, means connecting said anode of said valves to said control electrodes of the next succeeding said valves to place said valves in series cascade whereby said valves are sequentially operated, and means for controlling the conductivity of the first to operate of said valves.

2. In an electrical timing network, a pair of electrical conductors adapted to be supplied with an alternating potential, a plurality of electric valves arranged for sequential operation, each said valve having an anode and a cathode and a control electrode, and being of the discontinuous control type in which a control potential between said control electrode and said cathode controls the time at which said valve becomes conductive but which control potential is ineffective to control the magnitude of such conduction, a plurality of impedance networks, certain of said networks comprising a reactive element and a resistor in parallel connection, alternate ones of said valves having their said anodes electrically connected individually to one of said conductors through individual ones of said certain impedance networks and having their said cathodes connected to the other of said conductors, intermediate ones of said valves having their said anodes electrically connected individually to said other conductor through individual ones of said certain impedance networks and having their said cathodes connected to said one conductor, means connecting said anode of said valves to said control electrodes of the next succeeding said valves to place said valves in series cascade whereby said valves are sequentially operated, and means for controlling the conductivity of the first to operate of said valves, said reactive elements being arranged with respect to their associated resistors to retain their charge for at least the period of the alternating current supply.

3. In an electronic timer, a pair of valves, each said valve having an anode and a cathode and a control electrode and being of the discontinuous control type in which said control electrode is ineffective subsequent to said valve being rendered conductive, a pair of conductors adapted to be supplied with an alternating potential, means including an energy storage device connecting said anode of one of said valves to one of said conductors, means connecting said one valve cathode to the other of said conductors, means connecting said cathode of the other of said valves to said one conductor, means including an apparatus which when energized establishes a voltage thereacross connecting said other valve anode to said other conductor, means connecting said other valve control electrode to said one valve anode, and circuit means adapted when energized to apply a control potential between said cathode and said control electrode of said one valve.

4. In an electrical timing network, a pair of electrical conductors adapted to be supplied with alternating potential, a plurality of electric valves arranged for sequential operation, each said valve having an anode and a cathode and a control electrode, each said valve being of the discontinuous control type in which the control potential between said control electrode and said cathode determines the time that said valve is rendered conductive and which when once

rendered conductive is uninfluenced by said control potential, certain ones of said valves having their respective said anodes connected to one of said conductors and their respective said cathodes connected to the other of said conductors, certain other of said valves having their respective said anodes connected to said other conductor and their respective said cathodes connected to said one conductor, impedance means connected in series between certain of said anodes and the one of said conductors to which they are connected, said certain ones of said valves being alternately arranged with said certain other of said valves, means connecting said anode of each said sequentially arranged valves with said control electrode of the respective next to operate said valve, and means for controlling the conductivity of the first to operate of said alternately arranged valves.

5. In an electrical timing network, a pair of electrical conductors adapted to be supplied with alternating potential, a plurality of discontinuous control type electric valves arranged for sequential operation, each said valve having an anode and a cathode and a control electrode, each said valve being of the discontinuous control type in which the control potential between said control electrode and said cathode determines the time that said valve is rendered conductive and which when once rendered conductive are uninfluenced by said control potential, certain ones of said valves having their respective said anodes connected to one of said conductors and their respective said cathodes connected to the other of said conductors, certain other of said valves having their respective said anodes connected to said other conductor and their respective said cathodes connected to said one conductor, electrical conducting elements connected in series between certain of said anodes and the one of said conductors to which they are connected, said elements acting to establish a potential thereacross as a consequence of a potential being applied thereto, said certain ones of said valves being alternately arranged with said certain other of said valves, means connecting said anode of each said sequentially arranged valves with said control electrode of the respective next to operate said valve whereby the potential produced by the one of said elements associated with said respective anode will produce said control potential for the valve having said respective control electrode, means for controlling the conductivity of the first to operate of said alternately arranged valves, another discontinuous control type valve having main electrodes connected between said pair of conductors and having a pair of control electrodes, means connecting one of said pair of grids to one of said elements, and means connecting the other of said pair of control electrodes to another of said elements.

6. In an electrical timing network, a pair of conductors adapted to be supplied with an alternating potential, a plurality of circuit elements adapted when energized to produce a control potential, a series of discontinuous control type valves, each said valve having an anode and a cathode and a control electrode, each said anode being connected individually with an individual one of said elements, said elements associated with alternate ones of said valves being connected to one of said conductors, said elements associated with the valves intermediate said alternate valves being connected to the

other of said conductors, means connecting the control electrode of each said valve to the one of said elements associated with the next preceding one of said valves whereby the voltage produced by said element associated with said next prior valve provides a control voltage between said electrode and said cathode of said valve following said prior valve, certain of said elements comprising a chargeable element and means to control the discharge of said chargeable element whereby the potential established thereby is maintained for a predetermined time interval subsequent to the rendering nonconductive the one of said valves associated therewith.

7. In an electrical timing network, a pair of terminals adapted to be supplied with an alternating potential, a plurality of discontinuous control type valves arranged for sequential operation, said valves being arranged in two groups with said valves of one of said groups alternately arranged with said valves of the other of said groups, each said valves having an anode and a cathode and a control electrode, a plurality of voltage establishing elements, each said element being operable when energized to establish a potential thereacross, means individually connecting the anode of the valves of said one group individually to certain of said voltage means, means connecting said certain voltage elements to one of said terminals and the cathodes of said one group to the other of said terminals, individually connecting the anodes of the valves of said other groups individually to other of said voltage elements, means connecting said other voltage elements to said other terminal and the cathodes of said other group to said one terminal, means for applying a voltage produced by said voltage element associated with a preceding valve between said control electrode and said cathode of the next valve following said preceding valve, and means for controlling the potential between said cathode and said control electrode of the first valve to be operated of said plurality of valves.

8. In an electrical timing network, a pair of terminals adapted to be supplied with an alternating potential, a pair of discontinuous-type control valves, each said valve having an anode and a cathode and a control electrode, an energy storage network, means connecting said network between one of said terminals and said anode of one of said valves, means connecting said one valve cathode to the other of said terminals, means connecting the cathode of the other of said valves to said one terminal, a control means, means connecting said control means between said other valve anode and said other terminal, means connecting said control electrode and said cathode of said other valve to receive a control potential from said storage network.

9. The combination of claim 8 in which said storage network comprises a parallelly connected reactive impedance and a resistor and in which said last-named means comprises a conductor connecting said other valve control electrode to said one valve anode.

10. In an electrical timing network, a pair of conductors adapted to be supplied with an alternating potential, a first and a second discontinuous control-type valve, said first valve having an anode and a cathode, said second valve having an anode and a cathode and a control electrode, an energy storage network comprising an energy storage device and means controlling the discharge of said device, circuit

means connecting said network between said first valve anode and one of said conductors, means connecting said second valve cathode to said one conductor, means connecting said first valve cathode to the second of said conductors, a conductor connecting said control electrode to said first valve anode, and means for controlling flow of current through said storage network.

11. The combination of claim 10 in which a control means is connected between said second valve anode and said other conductor.

12. In a welding timer, a pair of conductors adapted to be supplied with an alternating potential, a plurality of discontinuous control-type valves, each said valve having an anode and a cathode and a control electrode, a plurality of energy storage networks comprising a capacitor and a resistor connected in parallel, a first of said networks being connected between the anode of a first of said valves and one of said conductors, a first conductor connecting said first valve cathode to the other of said conductors, a second of said networks being connected between the anode of a second of said valves and said other conductor, a second conductor connecting said second valve cathode to said one conductor, a third of said networks being connected between the anode of a third of said valves and said one conductor, a third conductor connecting said third valve cathode to said other conductor, a transformer having a primary winding and a first and a second secondary winding, said primary winding being connected between the anode of a fourth of said valves and said other conductor, a fourth conductor connecting said fourth valve cathode to said one conductor, a fourth of said networks connected between the anode of a fifth of said valves and said one conductor, a fifth conductor connecting said fifth valve cathode to said other conductor, means connecting a fifth of said networks between the anode of a sixth of said valves and said other conductor, a sixth conductor connecting said sixth valve cathode to said one conductor, means connecting said second valve control electrode to said first valve anode, means connecting said third valve control electrode to said second valve anode, means connecting said fourth valve control electrode to said third valve anode, means connecting said first secondary winding between said fifth valve control electrode and said fifth valve cathode, means connecting said sixth valve control electrode to said fifth valve anode, control means connecting the anode of a seventh of said valves to said other conductor, a seventh conductor connecting said seventh valve cathode to said one conductor, said seventh valve having a second control electrode, means connecting said second secondary winding between one of said seventh valve control electrodes and said seventh valve cathode, means connecting the other of said seventh valve control electrodes to one of said valve anodes, means connected to provide a control potential between said first valve control electrode and said first valve cathode, and means actuated as a consequence of the potential appearing across said fifth network for controlling said last-named means.

13. The combination of claim 12 in which said first and said third and said fourth and said fifth networks have a discharge time in excess of several periods of said source.

14. In an electric timer, a pair of conductors adapted to be supplied with an alternating potential, a series of discontinuous control-type

valves, each said valve having an anode and a cathode and a control electrode, circuit means connecting said valves between said conductors so that the cathodes of alternate first ones of said valves are connected to one of said conductors and the cathodes of alternate second ones of said valves are connected to the other of said conductors, electrical devices individually connected to each of said anodes, means connecting the devices associated with said alternate first valves to said other conductor and the devices associated with said alternate second valves to said one conductor, means connecting the control electrodes of said alternate second valves to the anodes of the next preceding alternate first valve, a control network comprising another discontinuous control-type valve having an anode and a cathode and a control electrode, means connecting said network between said other conductor and the control electrode of the first one of said alternate first valves whereby the conductivity of said last-named another valve controls said first one valve, and means applying a potential established by the last of said alternate second valves between the control electrode and cathode of said last-named another valve.

15. The combination of claim 14 in which said control network controls the connection of said last alternate second valve to said other conductor.

16. In an electrical timing network, a pair of electrical conducting means adapted to be supplied with alternating potential whereby one of said means is positive and the other of said means is negative and conversely, a plurality of electric valves arranged for sequential operation, each said valve having an anode and a cathode and a control electrode, each said valve being of the discontinuous control type in which the control potential between said control electrode and said cathode determines the time that said valve is rendered conductive and which when once rendered conductive is uninfluenced by said control potential, certain ones of said valves having their respective said anodes connecting to said one conducting means and their respective said cathodes connected to said other conducting means, certain other of said valves having their respective said anodes connected to said other conducting means and their respective said cathodes connected to said one conducting means, said certain one and said certain other valves being arranged in pairs to provide a first and a second valve for each said pair of valves, impedance means connected in series between said anodes of each of said first of said pairs of valves and the one of said conducting means to which they are connected, said second of said pairs of valves being oppositely arranged with said first of said pairs of valves between said conducting means, means connecting said anode of each of said first of said pairs of valves with said control electrode of the second of said pairs of said valves, and means for controlling the conductivity of the first to operate of said sequentially arranged valves.

17. In an electrical timing network, a pair of electrical conductors adapted to be supplied with alternating potential, a plurality of discontinuous control-type electric valves arranged for sequential operation, each said valve having an anode and a cathode and a control electrode, each said valve being of the discontinuous control type in which the control potential between said control electrode and said cathode determines the time that said valve is rendered conductive and which

when once rendered conductive are uninfluenced by said control potential, a certain one of said valves having its respective said anode connected to one of said conductors and its respective said cathode connected to the other of said conductors, certain other of said valves having their respective said anodes connected to said other conductor and their respective said cathodes connected to said one conductor, electrical conducting elements, certain of said elements being connected in series between certain of said anodes and the one of said conductors to which they are connected, said elements acting to establish a potential thereacross as a consequence of a potential being applied thereto, said certain one of said valves being alternately arranged with said certain other of said valves, means connecting said anode of each said sequentially arranged valve with said control electrode of the respective next to operate of said valve whereby the potential produced between one of said elements associated with said respective anode will produce said control potential for the valve having said respective control electrode, means for controlling the conductivity of the first to operate of said alternately arranged valves, another discontinuous control-type valve having main electrodes connected between said pair of conductors and having a pair of control electrodes, means connecting one of said pair of control electrodes to one of said elements, and means connecting the other of said pair of control electrodes to another of said elements.

18. In an electric timer, a pair of conducting means adapted to be supplied with an alternating potential, a series of discontinuous control-type valves, each said valve having an anode and a cathode and a control electrode, circuit means connecting said valves between said conducting means so the cathodes of alternate first ones of said valves are connected to one of said conducting means and the cathodes of alternate second ones of said valves are connected to the other of said conducting means, electrical devices individually connected to each of said anodes, means connecting said devices associated with said alternate first valves to said other conducting means and the devices associated with said alternate second valves to said one conducting means, means connecting the control electrodes of said alternate second valves to the anodes of the next preceding alternate first valve, a control network comprising another discontinuous control-type valve having an anode and a cathode and a control electrode, means connecting said network between said other conducting means and the control electrode of the first one of said alternate first valves whereby the conductivity of said last-named another valve controls said first one valve, and means applying a potential established by the last of said alternate second valves between the control electrode and cathode of said last-named another valve.

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