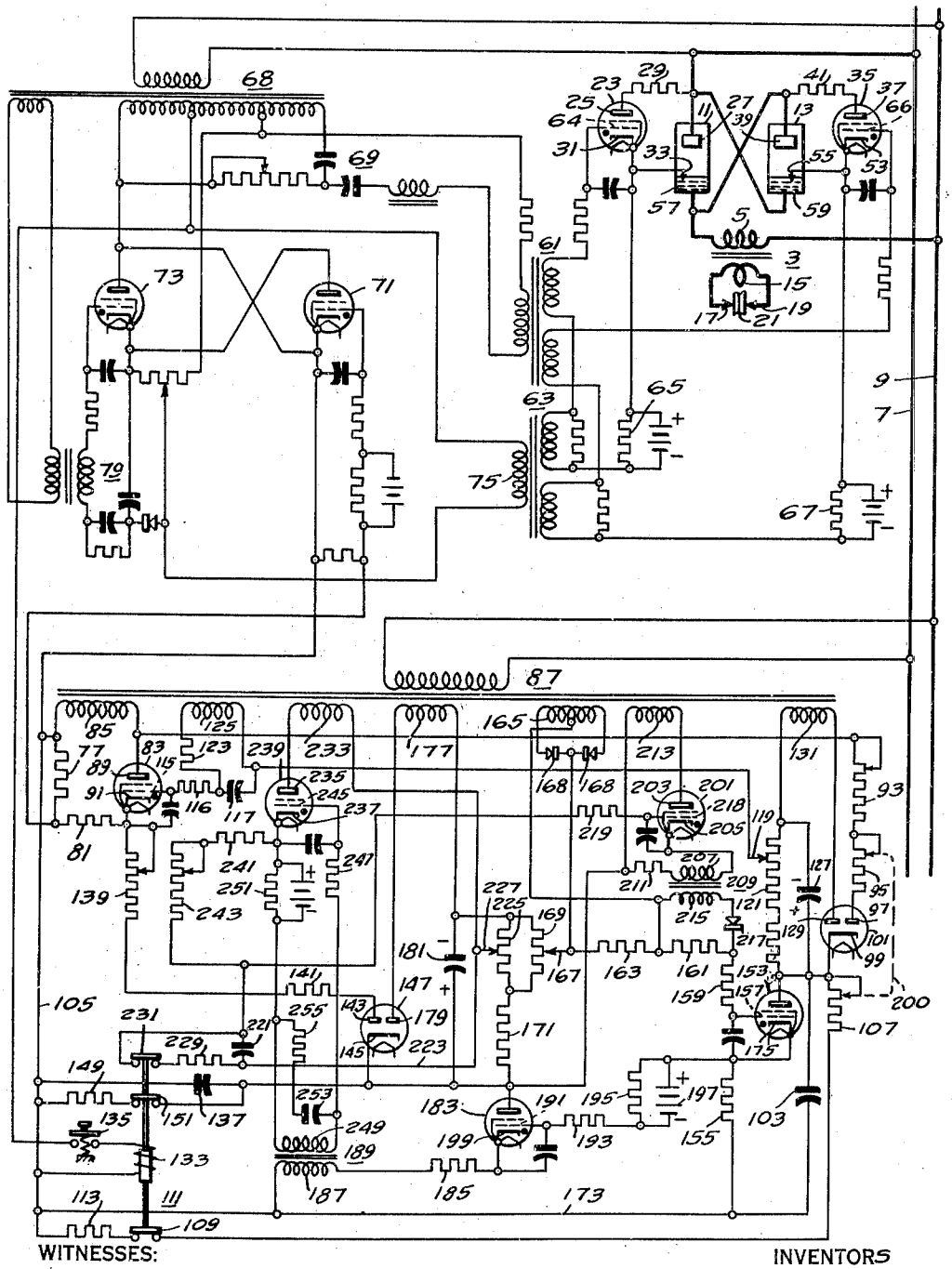
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ELECTRONIC TIMING SYSTEM

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ELECTRONIC TIMING SYSTEM

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This invention relates to an electronic timing system, and it has particular relation to a timing system for use with a resistance welder.

In a resistance seam welder or pulsation spot welder, as constructed in accordance with the teachings of the prior art, current is supplied from an alternating voltage source to the welding transformer in spaced impulses. Each impulse is a preselected number of half-periods of the supply voltage in length with a time interval of another preselected number of half-periods between successive impulses. The time during which current is supplied to the welding transformer is known as the on time period while the interval between successive impulses is known as the off time period. An overall timer is sometimes provided to prevent further supply of current to the welding transformer after a preselected number of complete operations, each of which comprises an on time and an off time period.

It is an object of our invention to provide a novel electronic timing system suitable for use in controlling a resistance seam welder or pulsation spot welder.

Another object of our invention is to provide a new and improved timing system for a seam welder or pulsation spot welder which is more reliable in operation and less expensive in both original and maintenance costs.

A further object of our invention is to provide a new and improved control circuit for use in supplying current to a load in spaced impulses with each impulse being of a predetermined length with a predetermined time interval between successive impulses.

Still another object of our invention is to provide a new and simplified system for timing a series of events, each of which comprises a first interval of a preselected length and a second interval of another preselected length.

A further object of our invention is to provide a new and improved control circuit for use in supplying current to a load in spaced impulses with each impulse being of a predetermined length with a predetermined time interval between successive impulses and incorporating apparatus for preventing further supply of current after a preselected number of impulses.

In accordance with our invention, we provide a timing system for use in supplying current to an impedance load from a voltage supply source which comprises a normally non-conductive electric control valve in series with the source and load. The valve is arranged to be conductive when a predetermined charge exists on a first capacitor and first circuit means are provided normally tending to effect charging of that first capacitor at a predetermined rate. Second circuit means are provided to effect charging of a second capacitor at a predetermined rate only while the valve is conductive. When the second capacitor attains a certain charge, a discharge circuit is completed across each of the capacitors until they are substantially discharged. Consequently, the valve becomes non-conductive a predetermined time interval after it first becomes conductive. Reoperation of the system is automatic until a preselected number of operations has been completed. At that time a blocking arrangement is operable to prevent recharging of the first capacitor and thereby to prevent further reoperation of the system.

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In a resistance welding system, the voltage developed across the impedance load while the valve is conductive may be used with a follow-up circuit to control the firing of a pair of inversely connected main valves interposed between an alternating supply voltage source and the primary winding of the welding transformer.

The novel features that I consider characteristic of my invention are set forth with particularity with the appended claims. The invention itself, however, together with additional objects and advantages thereof, may be best understood from the following description of a specific embodiment when read in connection with the accompanying drawing, in which:

The single figure is a schematic circuit diagram of a control system embodying my invention.

As shown in the drawing, a welding transformer 3 has its primary winding 5 connected between a pair of alternating voltage supply lines 7 and 9 through a pair of inversely connected electric valves 11 and 13 of the arc-like type, such as ignitrons. The secondary winding 15 of the welding transformer 3 is connected to supply current through a pair of welding electrodes 17 and 19 and the material 21 to be welded which is engaged therebetween.

Another electric discharge valve 23 of the arc-like type, preferably a gas-filled tube such as a thyratron, has its anode 25 connected to the anode 27 of the first ignitron 11 through a current-limiting resistor 29, and its cathode 31 connected to the igniter 33 of the first ignitron. Still another electric discharge valve 35 of the arc-like type, preferably a gas-filled tube, such as a thyratron, has its anode 37 connected to the anode 39 of the second ignitron 13 through a limiting resistor 41, and its cathode 53 connected to the igniter 55

of the second ignitron. These valves 23 and 35 are referred to hereinafter as the first and second firing valves, respectively.

During a half-period of the supply voltage of one polarity, the anode 27 of the first ignitron 11 is positive with respect to the cathode 57 of that ignitron. If the first firing valve 23 becomes conductive during that half-period, current flows through the first firing valve 23 and the igniter 33 and cathode 57 of the first ignitron 11 to render the latter conductive. Similarly, during a half-period of the supply voltage of opposite polarity, the anode 39 of the second ignitron 13 is positive with respect to the cathode 59 of that ignitron so that if the second firing valve 35 becomes conductive during that half-period, current flows through the igniter 55 and cathode 59 of the second ignitron 13 to render that ignitron conductive.

Operation of the firing valves 23 and 35 is controlled by the combined effects of a peaking transformer 61, a control transformer 63 and certain direct-current biasing voltages provided through resistors 65 and 67 in the control circuits of the firing valves extending from the control electrode 64 to the cathode 31 of the first firing valve 23 and from the control electrode 66 to the cathode 53 of the second firing valve 35. The peaking transformer 61 is energized from the alternating voltage supply lines through an auxiliary supply transformer 68 and a phase-shifting circuit 69 and tends to render the firing valves 23 and 35 conductive alternately in successive half-periods at a preselected instant in a half-period.

The tendency of the peaking transformer 61 to cause the firing valves 23 and 35 to become conductive is normally overcome by the control transformer 63 which is energized through the auxiliary transformer 68 to provide an alternating bias voltage. However, a pair of auxiliary valves 71 and 73, preferably of the arc-like type, such as thyratrons, are connected in inverse relation to each other and in parallel circuit relation with the primary winding 75 of the control transformer 63. When one of these auxiliary valves 71 and 73 is conductive, the bias voltage of the control transformer 63 is removed or substantially reduced so that the peaking transformer 61 is effective to render the corresponding one of the firing valves 23 and 35 conductive.

The first auxiliary valve 71 is arranged to become conductive in a positive half-period only when a voltage exists across an output resistor 77 of a suitable timing circuit. By a positive half-period is meant a half-period in which the voltage supplied across a valve is of such polarity that the valve conducts current if a suitable voltage is applied to its control electrode.

The second auxiliary valve 73 is controlled by a follow-up arrangement 79 so that it always becomes conductive in each half-period immediately following a half-period in which the first auxiliary valve 71 is conductive. Thus, as long as a voltage exists across the output resistor 77 in each positive half-period of the first auxiliary valve 71, the ignitrons 11 and 13 are rendered conductive alternately in successive half-periods. When no voltage exists across the output resistor 77, the ignitrons remain non-conductive.

A more complete description of the ignitron circuits, the control circuits for the firing valves 23 and 35, the energizing circuits for the peaking transformer 61 and control transformer 63, and the follow-up arrangement, as well as the operation thereof, may be found in the copending application of E. C. Hartwig, W. E. Large and C. B. Stadum, Serial No. 702,204, filed October 9, 1946.

The output resistor 77 of the timing circuit is connected in series with another resistor 81 and a control valve 83 across the terminals of a secondary winding 85 of a supply transformer 87 energized from the supply lines. The control valve 83 is preferably of the arc-like type, such as the thyratron, and has its anode 89 connected to the right-hand terminal of the secondary winding 85 while its cathode 91 is connected through the resistors 77 and 81 to the left-hand terminal. Thus, the output resistor 77 is energized only while the control valve 83 is conductive.

Another circuit extends from the right-hand terminal of the secondary winding 85 through two adjustable resistors 93 and 95, the anode 97 and cathode 99 of a rectifier tube 101, an off time capacitor 103 and a conductor 105 to the left-hand terminal of the secondary winding 85. A discharge circuit is provided across the off time capacitor 103 which includes an adjustable resistor 107, an originally closed contact 109 of a relay 111 and another resistor 113.

The control circuit of the control valve 83 may be traced from the control electrode 115 thereof through a grid resistor 116, an auxiliary capacitor 117 to an intermediate tap 119 on a potentiometer 121 and from the lower terminal of the potentiometer 121 through the off time capacitor 103, the conductor 105 and the resistors 77 and 81 to the cathode 91.

The auxiliary capacitor 117 is connected in circuit with a resistor 123 across another secondary winding 125 of the supply transformer 87. The arrangement results in an alternating voltage appearing across the auxiliary capacitor 117 which leads the anode-to-cathode voltage of the control valve 83 by approximately 90°.

The potentiometer 121 is connected in shunt across another capacitor 127 which is connected in series with another anode 129 and the cathode 99 of the rectifier tube 101 across still another secondary winding 131 of the supply transformer 87. Consequently, a unidirectional biasing voltage appears across the portion of the potentiometer 121 in the control circuit of the control valve 83 which tends to maintain the control electrode 115 negative with respect to the cathode 91. The combined voltage of the potentiometer 121 and the auxiliary capacitor 117 in the control circuit of the control valve 83 is normally sufficient to maintain the control valve non-conductive. However, it is apparent that if the contact 109 of the relay 111 is opened to break the discharge circuit across the off time capacitor 103, that capacitor is charged at a predetermined rate through the rectifier tube 101. The polarity of the charge on the off time capacitor 103 is such that the control electrode 115 of the control valve 83 becomes more positive. Consequently, when the charge on the off time capacitor 103 attains a predetermined value, the resultant voltage in the control circuit of the control valve 83 becomes more positive than the critical value of the valve which is necessary to render the control valve conductive in a positive half-period. Because of the pulsations provided across the auxiliary capacitor 117, the control valve 83 is rendered conductive near the beginning of each positive half-period so long as the charge on the off time capacitor is at least as great as is necessary to make the resultant voltage more positive than the critical value.

The operating coil 133 of the relay 111 is con-

nected to be energized from the auxiliary transformer 68 upon closure of a starting device, such as the push-button switch 135. It is then evident that the control valve 83 is rendered conductive a predetermined time interval after closure of the push-button switch 135, which closure results in breaking the discharge circuit across the off time capacitor 103 to permit that capacitor to be charged. The length of the time interval depends, of course, upon the rate of charge of the capacitor 103 which is determined by the setting of the adjustable resistors 93 and 95 in the charging circuit. This time interval is the off time period.

While the control valve 83 is rendered conductive in successive positive half-periods, the output resistor 77 is energized to effect firing of the ignitrons 11 and 13 controlling the welding transformer. A second on time capacitor 137 is connected in parallel circuit relation with the output resistor 77 to be charged by current flowing through the control valve 83. This circuit may be traced from the cathode 91 of the control valve 83 through an adjustable resistor 139, another resistor 141, the anode 143 and cathode 145 of another rectifier tube 147, the on time capacitor 137 and the conductor 105 to the left-hand terminal of the secondary winding 85. A discharge circuit is provided across the on time capacitor 137 through a resistor 149 and another originally closed contact 151 of the relay 111.

It is thus evident that so long as the relay 111 is energized, the on time capacitor 137 is charged only while the control valve 83 is conductive at a rate determined by the setting of the adjustable resistor 139.

An additional discharge circuit is provided across the off time capacitor 103 which includes another normally non-conductive valve 153, preferably of the arc-like type, such as a thyratron, and a resistor 155. The control circuit of this valve 153 may be traced from the control electrode 157 through a grid resistor 159, another resistor 161, still another resistor 163 to an intermediate terminal 167 on a potentiometer 169 and from the lower terminal of the potentiometer 169 through another resistor 171, the on time capacitor 137, a conductor 173 and the resistor 155 in the auxiliary discharge circuit of the off time capacitor 137 to the cathode 175 of the valve.

Originally, no voltage appears across the resistor 161 in the control circuit of the valve 153 but a pulsating unidirectional voltage having the wave form of a full wave, rectified and inverted alternating voltage appears across the resistor 163 derived from another secondary winding 165 of the supply transformer 87 through rectifiers 168.

The potentiometer 169 is connected in series with the resistor 171 across another secondary winding 177 of the supply transformer 87 through another anode 179 and the cathode 145 of the rectifier tube 147. A capacitor 181 is connected in shunt across the series connected potentiometer 169 and resistor 171 so that a smoother direct-current biasing voltage is impressed in the control circuit of the valve 153 by the potentiometer 169 and resistor 171. The combination of the biasing voltage across the potentiometer 169 and resistor 171 and the voltage across the other resistor 163 is sufficiently negative to maintain the valve 153 normally non-conductive. However, when a predetermined charge is attained on the on time capacitor 137, the resultant voltage in the control circuit of the valve 153 renders that valve conductive at the beginning of each half-period of the alternating voltage supply. When the valve 153 is rendered conductive, it remains conductive until the off time capacitor 103 is substantially completely discharged therethrough. The discharge of the off time capacitor 103 is quite rapid and upon its discharge below the predetermined value, the control valve 83 no longer becomes conductive.

Another auxiliary discharge circuit is provided across the on time capacitor 137 through another valve 183, a resistor 185 and the primary winding 187 of an auxiliary transformer 189. This valve 183 also is preferably of the arc-like type, such as a thyratron, and is normally nonconductive.

The control circuit of the valve 183 may be traced from its control electrode 191 through a grid resistor 193, another resistor 195 across which a biasing voltage is provided from a suitable source represented by a battery 197, the resistor 155 in the auxiliary discharge circuit of the off time capacitor 103, the primary winding 187 of the auxiliary transformer 189 and the resistor 185 to the cathode 199. The biasing voltage across the resistor 195 is normally sufficient to maintain the valve 183 non-conductive. However, when the auxiliary discharge circuit across the off time capacitor 103 is completed, current flows through the valve 153 and the resistor 155 to develop a voltage pulse across the resistor 155. This voltage pulse is sufficient to overcome the biasing voltage and render the valve 183 conductive to complete the discharge circuit across the on time capacitor 137. Thus when the on time capacitor 137 attains a predetermined charge, a discharge circuit is completed across each of the capacitors 103 and 137 to effect substantial discharge thereof. It is then apparent that recharging of the off time capacitor 103 is begun and the control valve 83 again becomes conductive after an off time interval.

It is to be noted that there is preferably a mechanical interconnection, represented by the dotted line 200, between the adjustable arms of the resistor 95 in the charging circuit of the off time capacitor 103, and of the resistor 107 in the originally closed discharge circuit of the off time capacitor. The arrangement provides a greater resistance in the discharge circuit when the rate of charge is less. The purpose of this interconnection is to decrease the first off time period when the setting for the off time period is increased. The first off time period occurs before any welding current is supplied and so need not be of the same length as subsequent off time periods to effect a good weld. This first off time period may be made shorter by increasing the resistance in the originally closed discharge circuit which increases the original charge on the off time capacitor so that the capacitor need not receive so much additional charge before the on time period begins. The interconnection between the arms of resistors 95 and 107 enables an appropriate resistance to be maintained in the discharge circuit.

A blocking arrangement is provided to halt the operation of the timing circuit after a predetermined number of on time intervals. The blocking circuit includes a blocking valve 201, preferably of the arc-like type, such as a thyratron, having its anode 203 and cathode 205 connected in series with the primary winding 207 of an auxiliary transformer 209 and a resistor 211 across

another secondary winding 213 of the supply transformer 87. The secondary winding 215 of the auxiliary transformer 209 is connected through a rectifier 217 across the resistor 161 in the control circuit of the valve 153 in the auxiliary discharge circuit of the off time capacitor 103. Thus, when the blocking valve 201 is conductive in positive half-periods, a voltage appears across the resistor 161 in the control circuit of the valve 153 which is of such polarity and magnitude as to render the valve 153 conductive regardless of the condition of charge or discharge of the on time capacitor 137. Consequently, effective charging of the off time capacitor 103 is prevented so long as the valve 153 becomes conductive in each positive half-period.

The control circuit of the blocking valve 201 may be traced from the control electrode 218 thereof through a grid resistor 219, a blocking capacitor 221, a conductor 223 to an intermediate tap 224 on another potentiometer 225 in shunt with potentiometer 169 and from the lower terminal of potentiometer 225 through resistor 171, the resistor 211 and primary winding 207 to the cathode 205. The blocking valve 201 is normally maintained non-conductive by the biasing voltage provided by potentiometer 225 and resistor 171.

A discharge circuit is provided across the blocking capacitor 221 and includes a resistor 229 and another originally closed contact 231 of the relay 111. The blocking capacitor 221 is also connected in a circuit extending from the left-hand terminal of another secondary winding 233 of the supply transformer 87 through the anode 235 and cathode 237 of another valve 239, a resistor 241, an adjustable resistor 243, and the blocking capacitor 221 and conductor 223 to the right-hand terminal of the secondary winding 233. Therefore, while relay 111 is energized, the blocking capacitor 221 is charged at a predetermined rate, determined by the setting of the adjustable resistor 243, whenever the valve 239 is conductive.

The control circuit of the valve 239 may be traced from its control electrode 245 through a grid resistor 247, the secondary winding 249 of the auxiliary transformer 189, and another resistor 251 to the cathode 237. A capacitor 253 and resistor 255 are connected in series across the secondary winding 249. A biasing voltage appears across the resistor 251 which is normally sufficient to maintain the valve 239 non-conductive. However, an additional voltage pulse is introduced into the control circuit of the valve 239 upon a discharge of the on time capacitor 137 through the primary winding 187 of the auxiliary transformer 189. Since the voltage pulse is of extremely short duration and occurs at the very beginning of a positive half-period of the valve 239, the capacitor 253 is provided to insure the valve becoming conductive for one half-period to supply an increment of charge to the blocking capacitor 221. While valve 239 does not become conductive until after valve 183 becomes conductive, and valve 183 follows valve 153, the action is so fast that valve 239 becomes conductive very near the beginning of a half-period. Consequently, the blocking capacitor 221 is charged in steps, receiving a predetermined increment of charge each time the on time capacitor 137 is discharged. After a preselected number of discharging operations of the on time capacitor, as determined by the setting of the adjustable resistor 243, the blocking capacitor charge becomes sufficient to render the blocking valve 201 conductive and prevent further operation of the timing circuit.

The operation of the system may be initiated by closure of the push-button switch 135 to energize the relay 111. The relay contacts 109, 151 and 231 open the discharge circuits across the off time, on time and blocking capacitors 103, 137 and 221. As a result, charging of the off time capacitor 103 at a predetermined rate is initiated. After a predetermined time interval which may be relatively short because of the setting of the resistor 107, the off time capacitor 103 is sufficiently charged to cause the control valve 83 to become conductive in positive half-periods of its supply voltage.

While the control valve 83 is conductive, a voltage appears across the output resistor 77 to cause the first auxiliary valve 71 to become conductive. The connections are such that the positive half-periods of the first auxiliary valve 71 coincides with the positive half-periods of the control valve 83, the firing valve 23 and the corresponding ignitron 11.

When the first auxiliary valve 71 is conductive, it effectively removes the biasing voltage of the control transformer 63 permitting the firing valve 23 to render the ignitron 11 conductive at the instant of the half-period determined by the peaking transformer 61. In the next succeeding half-period, the second auxiliary valve 73 becomes conductive because of the follow-up arrangement, causing the other ignitron 13 to be rendered conductive. It is evident that when the control valve 83 becomes conductive in each positive half-period, the ignitrons 11 and 13 become conductive alternately in successive half-periods to supply current through the welding transformer 3.

While the control valve 83 is conductive, the on time capacitor 137 is charged at a predetermined rate. After another predetermined time interval, the on time capacitor 137 is sufficiently charged to render the valve 153 conductive to complete the auxiliary discharge circuit across the off time capacitor 103. The discharge of the off time capacitor 103 acts through the resistor 155 to render the other valve 183 conductive to complete the auxiliary discharge circuit across the on time capacitor 137. The discharge of the on time capacitor 137 through the auxiliary transformer 189 causes the valve 239 to become conductive for a single positive half-period to supply an increment of charge to the blocking capacitor 221. Unless the adjustable resistor 243 in the charging circuit of the blocking capacitor is set for but a single cycle of operation, the first increment of charge on the blocking capacitor 221 is insufficient to render the blocking valve 201 conductive.

When the off time capacitor 103 is discharged below the predetermined value, the control valve 83 no longer becomes conductive in a positive half-period. As the off time capacitor 103 is substantially discharged, the valve 153 in its auxiliary discharge circuit again becomes non-conductive and recharging of the off time capacitor is again initiated, the off time period then being the full length inasmuch as the discharge circuit through resistor 107 was not used. The operation is then repeated so that after a predetermined off time interval the control valve 83 becomes conductive and remains conductive for a predetermined on time interval.

After a preselected number of complete opera-

tions, as determined by the setting of the adjustable resistor **243** in the charging circuit of the blocking capacitor **221**, the charge on the blocking capacitor **221** becomes sufficient to render the blocking valve **201** conductive. A voltage pulse is then impressed in the control circuit of the valve **153** in the discharge circuit of the off time capacitor **103**, which pulse is sufficient to render the valve conductive in each half-period in which the capacitor tends to be charged. Thus, further operation of the timing circuit is prevented. A new series may be obtained by releasing the push-button switch **135** to reset the system and then reclosing it.

While the system illustrated assumes manual operation of the push-button switch **135** and that it be held closed throughout the weld, it will be apparent that the switch may be operated automatically as, for example, by sequencing circuits, or other suitable means of operating the relay **111** may be employed.

It is to be noted that the usual by-pass capacitors have been shown between the control electrode and cathode of each thyratron. The thyratrons have been illustrated as of the indirectly heated type but the usual connections for supplying current through the filaments have been omitted to avoid confusion in the drawing.

While we have shown and described a specific embodiment of our invention, we are aware that many modifications thereof might be made without departing from the spirit of the invention. It, therefore, is not our intention to limit our invention to that specific embodiment.

We claim as our invention:

1. A timing system for use in supplying current through a load from a voltage supply, comprising an electric valve in series with said source and load for controlling the flow of current through the load, a pair of capacitors, a first circuit normally tending to effect charging of one of said capacitors at a predetermined rate, a control circuit responsive to a predetermined charge on said one capacitor to cause the valve to be conductive, a second circuit effective only while the valve is conductive to cause charging of the other capacitor at a predetermined rate, and means operable in response to a predetermined charge on said other capacitor to effect temporary completion of a discharge circuit across each of the capacitors until they are substantially discharged.

2. A timing system for use in supplying current through a load from a voltage supply source, comprising a normally non-conductive electric valve in series with said source and load for controlling the flow of current through the load, a pair of capacitors, a starting device, first circuit means for charging one of said capacitors at a predetermined rate following operation of said starting device, control means responsive to a predetermined charge on said one capacitor to cause the valve to be conductive, second circuit means effective only while the valve is conductive to cause charging of the other capacitor at a predetermined rate, and means operable in response to a predetermined charge on said other capacitor to effect temporary completion of a discharge circuit across said one capacitor.

3. A timing system for use in supplying current through a load from a voltage supply source, comprising an electric valve in series with said source and load for controlling the flow of current through the load, a pair of capacitors, a first circuit normally tending to effect charging of one of said capacitors at a predetermined rate, a control circuit responsive to a predetermined charge on said one capacitor to cause the valve to be conductive, second circuit means effective only while the valve is conductive to cause charging of the other capacitor at a predetermined rate, means operable in response to a predetermined charge on said other capacitor to effect temporary completion of a discharge circuit across said one capacitor until it is substantially discharged, and means operable after said predetermined charge is attained on said other capacitor to effect temporary completion of a discharge circuit across said other capacitor until it is substantially discharged.

4. A timing system for use in supplying current through a load from a voltage supply source, comprising an electric valve in series with said source and load for controlling the flow of current through the load, a pair of capacitors, first circuit normally tending to effect charging of one of said capacitors at a predetermined rate, a control circuit responsive to a predetermined charge on said one capacitor to cause the valve to be conductive, second circuit effective only while the valve is conductive to cause charging of the other capacitor at a predetermined rate, means operable in response to a predetermined charge on said other capacitor to effect temporary completion of a first discharge circuit across said one capacitor until it is substantially discharged, and means operable in response to current through said first discharge circuit to effect temporary completion of a second discharge circuit across said other capacitor until it is substantially discharged.

5. A timing system for use in supplying current through a load from a voltage supply source, comprising a normally non-conductive electric valve in series with said source and load, a pair of capacitors, first circuit means connecting one of said capacitors in parallel circuit relation with the series connected valve and load to effect charging of said one capacitor at a predetermined rate, control means responsive to a predetermined charge on said one capacitor to cause the valve to be conductive, second circuit means connecting the other capacitor in parallel circuit relation with the load and in series with the valve to be charged at a predetermined rate only while the valve is conductive, and means operable in response to a predetermined charge on said other capacitor to effect temporary completion of a discharge circuit across each of the capacitors until they are substantially discharged.

6. A timing system for use in supplying current through a load from an alternating voltage supply source, comprising a normally non-conductive electric valve in series with said source and load, a pair of capacitors, first circuit means including a rectifier connecting one of said capacitors in parallel circuit relation with the series connected valve and load to effect charging of said one capacitor at a predetermined rate, control means responsive to a predetermined charge on said one capacitor to cause the valve to be conductive in positive half-periods of said supply voltage, second circuit means including a rectifier connecting the other capacitor in parallel circuit relation with the load and in series with the valve to be charged at a predetermined rate while the valve is conductive, and means operable in response to a predetermined charge on said other capacitor to effect completion of a discharge circuit across each of the capacitors until they are substantially discharged.

7. A timing system for use in supplying current through a load from a voltage supply source, comprising a normally non-conductive control valve in series with said source and load, a pair of capacitors, first circuit means normally tending to effect charging of one of said capacitors at a predetermined rate, control means responsive to a predetermined charge on said one capacitor to cause the control valve to be conductive, second circuit means effective only while the control valve is conductive to cause charging of the other capacitor at a predetermined rate, a first discharge circuit connected across said one capacitor and including a first normally non-conductive auxiliary valve, a second discharge circuit connected across said other capacitor and including a second normally non-conductive auxiliary valve, and means for causing said auxiliary valves upon said other capacitor attaining a predetermined charge, to become conductive temporarily until said capacitors are substantially discharged.

8. A timing system for use in supplying current through a load from a voltage supply source, comprising a normally non-conductive control valve in series with said source and load, a pair of capacitors, first circuit means normally tending to effect charging of one of said capacitors at a predetermined rate, control means responsive to a predetermined charge on said one capacitor to cause the control valve to be conductive, second circuit means effective only while the control valve is conductive to cause charging of the other capacitor at a predetermined rate, a first discharge circuit connected across said one capacitor and including a first normally non-conductive auxiliary valve, means responsive to a predetermined charge on said other capacitor for causing said first auxiliary valve to be conductive temporarily until said one capacitor is substantially discharged, a second discharge circuit connected across said other capacitor and including a second normally non-conductive auxiliary valve, and means operable in response to a discharge of said one capacitor to cause the second auxiliary valve to be conductive temporarily until said other capacitor is substantially discharged.

9. A timing system for use in supplying current through a load from a voltage supply source, comprising a normally non-conductive electric valve in series with said source and load, a pair of capacitors, first circuit means connecting one of said capacitors in parallel circuit relation with the series connected valve and load to effect charging of said one capacitor at a predetermined rate, control means responsive to a predetermined charge on said one capacitor to cause the valve to be conductive, second circuit means connecting the other capacitor in parallel circuit relation with the load and in series with the valve to be charged at a predetermined rate only while the valve is conductive, a first discharge circuit connected across said one capacitor and including a first normally non-conductive auxiliary valve, a second discharge circuit connected across said other capacitor and including a second normally non-conductive auxiliary valve, and control means for causing said auxiliary valves upon said other capacitor attaining a predetermined charge, to become conductive temporarily until said capacitors are substantially discharged.

10. A timing system for use in supplying current through a load from an alternating voltage supply source, comprising a normally non-conductive electric valve in series with said source and load, a pair of capacitors, first circuit means including a rectifier connecting one of said capacitors in parallel circuit relation with the series connected valve and load to effect charging of said one capacitor at a predetermined rate, control means responsive to a predetermined charge on said one capacitor to cause the valve to be conductive in positive half-periods of said supply voltage, second circuit means including a rectifier connecting the other capacitor in parallel circuit relation with the load and in series with the valve to be charged at a predetermined rate while the valve is conductive, a first discharge circuit connected across said one capacitor and including a first normally non-conductive auxiliary valve, a second discharge circuit connected across said other capacitor and including a second normally non-conductive auxiliary valve, and control means for causing said auxiliary valves upon said other capacitor attaining a predetermined charge, to become conductive temporarily until said capacitors are substantially discharged.

11. A timing system for use in supplying current through a load from an alternating voltage supply source, comprising a normally non-conductive electric valve in series with said source and load, a pair of capacitors, first circuit means including a rectifier connecting one of said capacitors in parallel circuit relation with the series connected valve and load to effect charging of said one capacitor at a predetermined rate, control means responsive to a predetermined charge on said one capacitor to cause the valve to be conductive in positive half-periods of said supply voltage, second circuit means including a rectifier connecting the other capacitor in parallel circuit relation with the load and in series with the valve to be charged at a predetermined rate while the valve is conductive, a first discharge circuit connected across said one capacitor and including a first normally non-conductive auxiliary valve, means responsive to a predetermined charge on said other capacitor for causing said first auxiliary valve to be conductive temporarily until said one capacitor is substantially discharged, a second discharge circuit connected across said other capacitor and including a second normally non-conductive auxiliary valve, and means operable in response to a discharge of said one capacitor to cause the second auxiliary valve to be conductive temporarily until said other capacitor is substantially discharged.

12. A timing system for use in supplying current through a load from a voltage supply source, comprising a normally non-conductive electric valve in series with said source and load for controlling the flow of current through the load, a pair of capacitors, first circuit means normally tending to effect charging of one of said capacitors at a predetermined rate, control means responsive to a predetermined charge on said one capacitor to cause the valve to be conductive, second circuit means effective only while the valve is conductive to cause charging of the other capacitor at a predetermined rate, means operable in response to a predetermined charge on said other capacitor to effect completion of a discharge circuit across each of the capacitors until they are substantially discharged, and means operable after said capacitors have been discharged a preselected number of times to prevent recharging of said one capacitor.

13. A timing system for use in supplying current through a load from a voltage supply source,

comprising a normally non-conductive electric valve in series with said source and load for controlling the flow of current through the load, a pair of capacitors, first circuit means normally tending to effect charging of one of said capacitors at a predetermined rate, control means responsive to a predetermined charge on said one capacitor to cause the valve to be conductive, second circuit means effective only while the valve is conductive to cause charging of the other capacitor at a predetermined rate, means operable in response to a predetermined charge on said other capacitor to effect completion of a discharge circuit across each of the capacitors until they are substantially discharged, and means responsive to each discharge of said other capacitor and operable after a preselected number of such discharges to prevent recharging of said one capacitor.

14. A timing system for use in supporting current through a load from a voltage supply source, comprising a normally non-conductive electric valve in series with said source and load for controlling the flow of current through the load, a pair of capacitors, first circuit means normally tending to effect charging of one of said capacitors at a predetermined rate, control means responsive to a predetermined charge on said one capacitor to cause the valve to be conductive, second circuit means effective only while the valve is conductive to cause charging of the other capacitor at a predetermined rate, means operable in response to a predetermined charge on said other capacitor to effect completion of a discharge circuit across each of the capacitors until they are substantially discharged, a third capacitor, means responsive to each discharge of said pair of capacitors for providing an increment of charge on the third capacitor, and means responsive to a predetermined charge on the third capacitor for preventing recharging of said one capacitor.

15. A timing system for use in supplying current through a load from a voltage supply source, comprising a normally non-conductive electric valve in series with said source and load for controlling the flow of current through the load, a pair of capacitors, first circuit means normally tending to effect charging of one of said capacitors at a predetermined rate, control means responsive to a predetermined charge on said one capacitor to cause the valve to be conductive, second circuit means effective only while the valve is conductive to cause charging of the other capacitor at a predetermined rate, a first discharge circuit connected across said one capacitor and including a first normally non-conductive auxiliary valve, a second discharge circuit connected across the other capacitor and including a second normally non-conductive auxiliary valve, means for causing said auxiliary valves upon said other capacitor attaining a predetermined charge, to become conductive temporarily until said pair of capacitors are substantially discharged, a third capacitor, means responsive to each discharge of said pair of capacitors for providing an increment of charge on the third capacitor, and means responsive to a predetermined charge on the third capacitor for causing said first auxiliary valve to be conductive regardless of the charge on said other capacitor to prevent recharging of said one capacitor.

16. A timing system comprising a capacitor, means adapted to function as a source of voltage, first circuit means connecting said source with said capacitor and tending to charge the capacitor at a predetermined rate, means responsive to a predetermined charge on the capacitor for temporarily completing a discharge circuit thereacross until the capacitor is discharged, an originally closed shunt circuit across said capacitor, and a starting device for opening said shunt circuit, said shunt circuit including impedance means affording an original charge on the capacitor to cause the time required for the capacitor to reach said predetermined charge immediately following operation of said starting device to be substantially less than the time required following discharge of the capacitor through the discharge circuit.

17. Apparatus according to claim 16 in which said first circuit means includes an adjustable impedance having an adjusting member for setting the rate of charge of the capacitor and said impedance means is adjustabe and has an adjusting arm, and which includes means interconnecting said arm and member for simultaneous and corresponding adjustment thereof.

18. A timing system for use in supplying current through a load from a voltage supply, comprising an electric valve in series with said source and load for controlling the flow of current through the load, a pair of capacitors, a first circuit normally tending to effect charging of one of said capacitors at a predetermined rate, a control circuit responsive to a predetermined charge on said one capacitor to cause the valve to be conductive, second circuit means effective to cause charging of the other capacitor at a predetermined rate, and means operable in response to a predetermined charge on said other capacitor to effect temporary completion of a discharge circuit across each of the capacitors until they are substantially discharged.

19. A timing system for use in supplying current through a load from a voltage supply, comprising an electric valve in series with said source and load for controlling the flow of current through the load, a pair of capacitors, a first circuit normally tending to effect charging of one of said capacitors at a predetermined rate, a control circuit responsive to a predetermined charge on said one capacitor to cause the valve to be conductive, a second circuit effective to cause charging of the other capacitor at a predetermined rate, means operable in response to a predetermined charge on said other capacitor to effect temporary completion of a discharge circuit across said one capacitor until it is substantially discharged, and means operable after said predetermined charge is attained on said other capacitor to effect temporary completion of a discharge circuit across said other capacitor until it is substantially discharged.

20. A timing system for use in supplying current through a load from a voltage supply, comprising an electric valve in series with said source and load for controlling the flow of current through the load, a pair of capacitors, a first circuit normally tending to effect charging of one of said capacitors at a predetermined rate, a control circuit responsive to a predetermined charge on said one capacitor to cause the valve to be conductive, a second circuit effective to cause charging of the other capacitor at a predetermined rate, means operable in response to a predetermined charge on said other capacitor to effect temporary completion of a first discharge circuit across said one capacitor until it is substantially discharged, and means operable in response to

current through said first discharge circuit to effect temporary completion of a second discharge circuit across said other capacitor until it is substantially discharged.

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