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ELECTRONIC CONTROL SYSTEM

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Fig. 1.

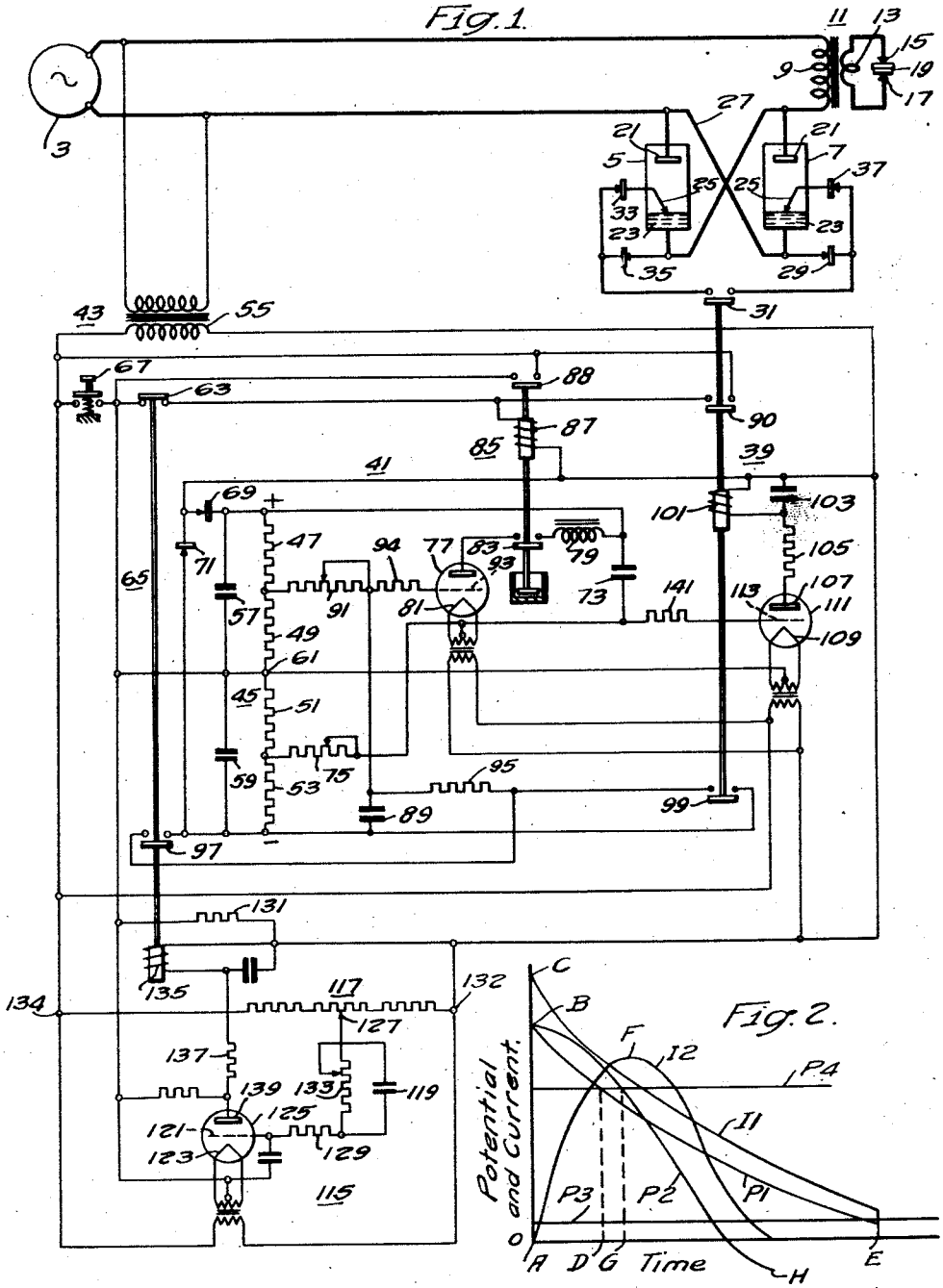


Fig. 2.

WITNESSES:

E. A. McCloskey.

John R. Shipman

INVENTORS

Robert W. Pearson and Donald P. Faulk.

BY

F. W. Lyle.

ATTORNEY

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ELECTRONIC CONTROL SYSTEM

Robert W. Pearson, Wilkinsburg, and Donald P. Faulk, Pittsburgh, Pa., assignors to Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., a corporation of Pennsylvania

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1 Claim. (Cl. 250—27)

This invention relates to an electronic control system, and has particular relation to pulsation welding apparatus.

In resistance spot welding good quality welds may be obtained by a method known as pulsation welding. A predetermined number of discrete impulses of current is supplied to the materials to be welded to produce each weld. Each impulse is of a predetermined length and there is a predetermined time interval between successive impulses. Since the welding apparatus is employed in welding a number of different materials having widely varying dimensions and properties, it is necessary that the control system be adjustable over a wide range to vary the length of the impulses as well as the length of the intervals between successive impulses.

A pulsation welding apparatus is described in a copending application of Robert W. Pearson and Slavo J. Murcek, Serial No. 412,660, filed September 27, 1941, and assigned to the Westinghouse Electric & Manufacturing Company. In this apparatus, current is supplied from a source to the welding transformer through a pair of ignitrons connected in anti-parallel. Firing of the ignitrons is controlled by an auxiliary alternating current circuit including an electric discharge control valve whose conductivity depends upon the potential of a control capacitor in its control circuit. When the capacitor potential is above a preselected value, the control valve is maintained non-conductive. When the capacitor potential is below the preselected value, the control valve conducts current in each positive half period of the alternating current. The auxiliary circuit also includes means operable when current is conducted through the control valve in each positive half period to effect a continuous supply of current through the ignitrons.

A source of direct current potential is arranged to constantly tend to charge the control capacitor through an adjustable resistor at a rate determined by the setting of the adjustable resistor. Another electric discharge device is connected in series with a current limiting resistor across the capacitor to form a discharge circuit therefor. When the discharge device is rendered conductive, the control capacitor is discharged therethrough and the control valve is rendered conductive. The discharge device becomes nonconductive when the control capacitor potential nears zero. Recharging of the control capacitor at the selected rate is commenced immediately upon extinguishment of the discharge device. As soon as the capacitor is recharged to a potential above the preselected value, conduction of current through the control valve is halted. Consequently, the time during which current is conducted through the control valve is made up of the time required to discharge the control capacitor from a potential just below the preselected value to a potential necessary to extinguish the discharge device, plus the time required to recharge the capacitor to the preselected value.

While the control valve is conductive in each positive half period, the discharge device is maintained non-conductive to permit uninterrupted recharging of the control capacitor. A predetermined interval of time after the control valve ceases to conduct in each positive half period, the discharge device is again rendered conductive and the operation of the system is then repeated. The length of the time interval depends upon the charging rate of a second capacitor in the control circuit of said device.

The apparatus of the copending application operates satisfactorily under many welding conditions. However, it has been found desirable in certain welding operations to effect the welding by passing extremely short current impulses through the material to be welded. For example, in apparatus energized from an alternating current source having a frequency of 60 cycles per second, it has been found that improved results are obtained if the welding current is supplied in impulses having a length of the order of 1 to 4 half cycles of the source. The length of the intervals between successive impulses need not be the same as the length of the impulses. However, the intervals should not be large enough to permit excessive loss of heat between impulses. From this standpoint, the intervals should have a length of approximately the same order as the impulses.

The length of the current impulses may be decreased in the apparatus of said copending application, by adjustment of the resistor in the charging circuit of the control capacitor. The length of the interval between successive impulses may be reduced by adjustment of the rate of charging of the second capacitor in the control circuit of the discharge device. However, when such adjustments are made to reduce the impulses and the intervals between impulses to the short length desired, the apparatus sometimes fails to function properly. The failure is evidenced by a continuing flow of welding current which, of course, ruins the weld in progress and the article being welded.

It is, accordingly, an object of our invention

to provide an improved low cost electronic timing system for pulsation welding apparatus for use in supplying short welding current impulses.

A more general object of our invention is to provide a new and improved system for supplying power from a source to a load in short discrete impulses.

Another object of our invention is to provide a new and improved arrangement for supplying power from a source to a load for a preselected interval of time during which current is supplied in short discrete impulses with a short interval of time between successive impulses.

An ancillary object of our invention is to provide an electronic system for successively charging and discharging a capacitor in short time periods.

More specifically, it is an object of our invention to provide an improved pulsation welding system in which current is supplied from an alternating current source in discrete impulses, each impulse enduring for a period of time of the order of 1 to 4 half periods of the source.

Our invention arises from the realization that the apparatus described in the copending application has certain properties which bring about the faulty operation. The discharge device in the discharge circuit of the control capacitor, which in practice is a WL–630 or an R. C. A. 2051 tube, is extinguished when the potential thereacross decreases below the arc-drop of the device. When the control capacitor is discharged through the device, the potential of the capacitor decreases exponentially. There is a constant tendency to recharge the control capacitor but the adjustable resistor in the charging circuit is ordinarily of such magnitude that the control capacitor cannot be recharged as fast as it is discharged. Consequently, the capacitor potential continues to decrease until the discharge device is extinguished. However, when the resistor in the charging circuit is adjusted to reduce the resistance and thereby shorten the time required to recharge the control capacitor, to the extent desired, the rate of charging becomes equal to the rate of discharging before the potential across the discharge device decreases below the arc-drop of the device. As a result, the device continues to conduct current. As long as the discharge device is conductive, the control capacitor cannot be recharged to render the control valve non-conductive.

The rate of discharging of the control capacitor may be increased, of course, by decreasing the magnitude of the current limiting resistor in series with the discharge device. However, the crest current through the device at the instant it is rendered conductive is then increased and exceeds the rating of the device. As a result, the device is burned out, or at least its life is greatly reduced.

According to our invention, the current limiting resistor in the discharge circuit of the control capacitor is replaced by an inductive reactor. As previously pointed out, the time of duration of a current impulse is made up of the time required to discharge the control capacitor from a potential just below the preselected value to a potential necessary to effect extinguishment of the discharge device, plus the time required to recharge the capacitor to the preselected potential. The use of the reactor according to our invention permits a reduction in both time periods and, therefore, permits the impulses to be reduced to the desired length.

The time of discharge of the control capacitor may be appreciably reduced without exceeding the crest current rating of the discharge device by use of the inductive reactance. The reactor tends to prevent a rapid change in current flow. Therefore, when the discharge device first becomes conductive, the reactor offers a high impedance to current flowing from the control capacitor and thereby prevents the suddenly applied capacitor potential from producing an immediate peak current of a high magnitude as would occur with a resistor only in the discharge circuit. As the capacitor potential decreases, the current flow decreases but the reactor tends to prevent the decrease in current and offers a lower impedance to current flow so that the capacitor is quickly discharged.

Since the inductive reactance tends to maintain the current flow, it also tends to drive the capacitor potential to zero and then charge the capacitor inversely. Consequently, the discharge device is positively extinguished even though the resistor in the charging circuit is adjusted to permit rapid recharging of the control capacitor.

The novel features that we consider characteristic of our invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and its method of operation, together with additional objects and advantages thereof, will best be understood from the following description of a specific embodiment when read in connection with the accompanying drawing, in which:

Figure 1 is a diagrammatic view illustrating an embodiment of our invention; and

Fig. 2 is a graph illustrating the operation of the embodiment of Fig. 1.

As illustrated in Figure 1, current is supplied from a source of alternating current **3** through a pair of ignitrons **5** and **7** connected in antiparallel to the primary **9** of the welding transformer **11**. The secondary **13** of the transformer is connected across the electrodes **15** and **17** in engagement with the materials **19** to be welded. Each of the ignitrons includes an anode **21**, a mercury pool cathode **23** and an igniter **25** in contact with the cathode. The ignition circuit of one of the ignitrons **5** may be traced from one side of the source **3** through a line **27**, a rectifier **29**, contactor **31**, a rectifier **33**, the igniter **25** and cathode **23** of the ignitron **5** and the primary **9** of the transformer **11** to the other side of the source. The ignition circuit of the other ignitron **7** may be similarly traced from the other side of the source **3** through the primary **9** of the transformer, a rectifier **35**, contactor **31**, a rectifier **37**, the igniter **25** and cathode **23** of the ignitron **7** to the source. Contactor **31** forms a part of a control relay **39** and is normally open. When contactor **31** is closed, the ignitrons **5** and **7** are rendered conductive alternately in successive half periods of the source.

The operation of the control relay **39** is controlled by a timing system indicated generally at **41**. Power is supplied to the system from the source **3** through an auxiliary transformer **43**. A voltage divider **45** having four sections **47**, **49**, **51**, and **53** is arranged to be energized from the secondary **55** of the auxiliary transformer **43**. A filter capacitor **57** is connected across the two upper sections **47** and **49** of the divider, and another filter capacitor **59** is connected across the two lower sections **51** and **53**. The center tap **61** of the divider **45** is connected through a push button switch **67** to one side of the secondary

55. The outer terminals of the voltage divider 45 are connected through rectifiers 69 and 71 to the other side of the secondary 55. The direction of current flow through the rectifiers 69 and 71 is such that the capacitor 57 across the two upper sections of the divider is charged in a first half period, and the other capacitor 59 across the two lower sections, is charged in the opposite half period. This rectifier capacitor arrangement is a typical voltage doubler circuit which is well-known in the art.

A control capacitor 73 is connected across the three upper sections 47, 49 and 51 of the divider through a variable resistor 75. An electric discharge device 77 of the arc-like type, in series with an inductive reactor 79, is connected directly across the control capacitor 73 with its cathode 81 connected to the negative plate of the capacitor. The circuit through the device 77 is controlled by a contactor 83 of another relay 85. The operating coil 87 of this relay 85 is energized from the secondary 55 of the auxiliary transformer through normally closed contactor 63 of relay 65 when the push button switch 67 is closed. A pair of holding circuits are connected across switch 67, one through contactor 88 of relay 85 and the other through contactor 90 of relay 39.

Another capacitor 89 is connected across the three lower sections 49, 51 and 53 of the divider through another variable resistor 91. The control circuit of the discharge device 77 extends from the grid 93 through a grid resistor 94, capacitor 89 to the negative terminal of divider 45, and thence through section 53 of the divider and resistor 75 to the cathode 81. When capacitor 89 is charged, its potential counteracts the biasing potential of section 53 and the grid 93 becomes positive with respect to the cathode 81, permitting the device 77 to be rendered conductive. However, when the capacitor 89 is discharged, the device 77 is prevented from becoming conductive by the negative potential appearing across section 53 of the divider. The capacitor 89 may be discharged through a resistor 95 by the closing of a normally open contact 97 of relay 65 or by the closing of another contact 99 of the control relay 39.

The operating coil 101 of the control relay 39 is arranged to be energized from the secondary 55 of the auxiliary transformer 43. The energizing circuit may be traced from one side of the secondary 55 through a parallel circuit consisting of the operating coil 101 on one side and a capacitor 103 on the other side, a current-limiting resistor 105, the anode 107 and cathode 109 of a control electric discharge valve 111, the center tap 61 of the divider 45, the contactor 88 of relay 85 to the other side of the secondary 55. The control valve 111 is of the arc-like type, and its grid 113 is connected to the negative plate of the control capacitor 73 through grid resistor 141.

The control circuit of the valve 111 extends from grid 113, through the control capacitor 73, sections 47 and 49 of divider 45 to the cathode 109. Section 51 of the divider 45 is also connected between the grid 113 and cathode 109. Thus, when the control capacitor is charged to a preselected potential, the grid 113 is negative with respect to the cathode 109. However, when the capacitor 73 is discharged below the preselected potential, the grid 113 becomes positive, permitting the control valve 111 to be rendered conductive in each positive half period of the source. The capacitor 103 in parallel with the operating coil 101 of the control relay 39 is of such dimensions that the coil is maintained energized between successive positive half periods. It is then evident that the control relay 39 is energized as long as the control capacitor potential remains below the preselected potential or, in other words, as long as the potential drop from the positive terminal of the divider across the capacitor to the grid 113 is less than the potential drop from the positive terminal to intermediate tap 61 which is connected to the cathode 109.

An overall timing system 115 is provided to limit the number of current impulses which may be supplied in one operation. A voltage divider 117 is connected directly across the secondary 55 of the auxiliary transformer 43. A capacitor 119 is then charged by the rectified leakage current through the grid 121 and cathode 123 of another electric discharge valve 125 of the arc-like type. The circuit for charging the capacitor 119 may be traced from the center tap 127 of the divider 117 through the capacitor 119, a grid resistor 129, the grid 121 and cathode 123 of the valve 125 and a small resistor 131 to one terminal 132 of the divider 117. The cathode 123 of the valve is also connected to the other terminal 134 of the divider 117 through the push button switch 67 and/or contactor 88. Thus, when the push button switch 67 and/or contactor 88 is closed, the cathode 123 of the valve 125 is connected to both sides of the voltage divider 117 and charging of the capacitor 119 is halted. The capacitor 119 then discharges through an adjustable resistor 133 in parallel therewith. The negative plate of the capacitor 119 is connected to the grid 121 of the valve 125 so that the valve remains non-conductive while the capacitor is charged. However, when the capacitor 119 becomes discharged, after an interval of time determined by the setting of the resistor 133, the valve 125 is rendered conductive. Current then flows from one terminal 132 of the voltage divider 117 through the operating coil 135 of the relay 65, and a current-limiting resistor 137 to the anode 139 of the valve 125. The circuit continues from the cathode 123 of the valve through the contactor 88 to the other side of the divider 117. Thus, a predetermined time interval after the push button 67 is first closed, the relay 65 is energized and one of its contactors 97 closes to maintain the capacitor 89 of the timing system 41 discharged, while the other contactor 63 breaks one of the holding circuits around push button switch 67.

To initiate a welding operation, the push button switch 67 is manually closed. Voltage divider 45 is then energized, and after a time delay, the relay 85 is operated to close the circuit through the discharge device 77. During the time delay, the control capacitor 73 and the other capacitor 89 are charged. When the circuit through the device 77 is closed by the contactor 83, the device immediately becomes conductive to discharge the control capacitor 73. The control capacitor 73 discharges to almost zero potential in a short but definite time interval, whereupon the device 77 becomes non-conductive. Immediately thereafter, recharging of the control capacitor 73 begins. However, during the discharge period the potential of the control capacitor 73 passes below the preselected value and the control valve 111 becomes conductive. The control valve then continues to conduct current in each positive half period of the source as long as the potential of control capacitor 73 remains below the pre-

selected value. The operating coil 101 of the control relay 39 is energized by current flowing through valve 111 and maintained energized between positive half periods by capacitor 103 to complete the firing circuits of the ignitrons 5 and 7. The ignitrons are then rendered conductive alternately in successive half periods to energize the welding transformer.

As the control capacitor 73 recharges, it eventually rises above the critical potential of the control valve 111 so that the valve no longer becomes conductive in the positive half periods. When the control valve 111 becomes non-conductive, the control relay 39 breaks the ignition circuits of the ignitrons, halting the flow of welding current.

As the control valve 111 becomes conductive, the control relay 39 is energized and its contactor 99 closes the discharging circuit of the capacitor 89. While this capacitor 89 is maintained in a discharged condition, the device 77 cannot become conductive so that recharging of the control capacitor 73 may proceed without interruption. However, when the control relay 39 is deenergized, the discharging circuit of the capacitor 89 is opened and recharging of the capacitor 89 at the selected rate is initiated. Upon charging of the capacitor 89 to a potential above the critical potential of the device 77, the latter is again rendered conductive to discharge the control capacitor 73 and another cycle of operation is started.

When the push button switch 67 is initially closed, the precharged capacitor 119 in the overall timing circuit 115 begins to discharge at a predetermined rate depending upon the setting of the resistor 133 in parallel therewith. This resistor is adjusted so that the capacitor potential drops to a point permitting firing of the valve 125 after a predetermined number of cycles of charging and discharging the control capacitor 73. When the valve 125 becomes conductive, the relay 65 is energized and its contactor 97 closes the discharging circuit of the capacitor 89 and maintains the capacitor in a discharged condition. As a result, further operation of the timing system 41 is prevented. Energization of relay 65 also opens contactor 63 to deenergize relay 85 whose contactor 83 breaks one of the holding circuits around switch 67. The other holding circuit is completed through contactor 90 of control relay 39 and is opened when the relay is deenergized. Thus, the welding operation is halted at the end of the next welding impulse.

The operation of the discharge circuit for the control capacitor 73 may be better understood by reference to the curve shown in Fig. 2. The potential of the control capacitor 73 and the current flowing through the discharge device 77 when the inductive reactance 79 is replaced by a resistor is represented by lines P1 and I1, respectively. The potential of the capacitor and the current flowing through the device with the reactor 79 in the circuit is represented by lines P2 and I2, respectively. The arc-drop of device 77 is represented by line P3 and the preselected value of capacitor potential which must be maintained to prevent the control valve 111 from being rendered conductive is represented by line P4.

When the device 77 is rendered conductive at a time A, the capacitor 73 has a high potential B. Assuming that the reactor 79 is replaced by a resistor, the current through the device immediately rises to a crest C. The height of the crest C for any given capacitor 73 and device 77 depends upon the magnitude of the resistor and must be kept below the safe maximum of the device. From the point B the capacitor potential decreases exponentially along line P1 and the current accordingly decreases from C along line I1. When P1 passes below line P4, as at D, the control valve 111 becomes conductive. When P1 passes below the arc-drop line P3, at point E, the device 77 is extinguished and current flow therethrough ceases. However, when the adjustable resistor 75 in the charging circuit of control capacitor 73 is set to allow the rapid recharging of the capacitor necessary to obtain the desired timing, the rate of charging equals the rate of discharging before line P1 passes below line P3. Under such conditions, P1 is prevented from passing below P3 and device 77 continues to conduct current. The control valve 111 is not rendered non-conductive until capacitor 73 is charged to a potential above line P4 and this cannot be accomplished while device 77 remains conductive.

When the reactor 79 is in the discharge circuit, as shown in Fig. 1, the potential of the capacitor 73 is also at point B in Fig. 2 when the device 77 becomes conductive. Because the inductive reactance 79 tends to oppose a rapid change in current flow, the current does not immediately rise to a high crest but increases gradually. The potential of the capacitor decreases rather slowly at first until the current peak F is nearly reached. Then because the inductive reactance tends to maintain the flow of current, the potential P2 of the capacitor decreases very rapidly passing below line P4 at some point G. The inductive reactance causes the device 77 to continue to conduct current for a short time after the capacitor potential P2 passes below line P3. However, the capacitor potential P2 is dropping very rapidly and if the device 77 is not extinguished sooner, the inductive reactance effects a flow of current which starts to charge the capacitor inversely, at which time, point H, the device 77 is certainly rendered non-conductive.

It is apparent from the curves in Fig. 2 that the time required to discharge the control capacitor from a point just below the line P4 to the extent necessary to extinguish the discharge device 77 may be less with the inductive reactance 79 in the circuit (points G to H) than with that inductive reactance replaced with a resistor (points D to E). This is true as long as the potential P4 remains at a value enabling proper operation of control valve 111. It is also to be noted that the crest F of the current I2 is lower than the crest C of the current I1. Then since the control capacitor can also be recharged to the preselected value P4 more rapidly with the inductive reactance in the circuit than with a resistor replacing the inductive reactor, the total time during which control valve 111 is conductive may be considerably reduced.

Although we have shown and described a specific embodiment of our invention, we are fully aware that many modifications thereof are possible. Our invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and by the spirit of the appended claim.

We claim as our invention:

For use in supplying power from a source of alternating current to a load, the combination comprising an electric discharge valve of the arc-like type interposed between said source and load, a control circuit for said valve including a normally charged capacitor, said control circuit being effective to render said valve conductive in

each positive half period of the source only while the potential of said capacitor has a certain relative magnitude with respect to a preselected value, a discharge circuit for said capacitor comprising an inductive reactance and a second electric discharge valve of the arc-like type connected in series across said capacitor, means for rendering said second valve conductive to discharge said capacitor, means for thereafter recharging said capacitor comprising a second source of potential and an impedance connected in series across said capacitor, said impedance means, potential source and capacitor being of such dimensions that the discharging rate of said capacitor would be equalled by the charging rate before the capacitor potential decreased below the arc-drop of said device if said reactance were replaced by a resistor of such dimensions as to prevent an excessive crest current through said device, whereby the capacitor potential rises above said preselected value in a time interval of the order of 1 to 4 half-periods of said first source after said second valve is rendered conductive, timing means for effecting re-operation of said means for rendering the valve conductive after a predetermined time delay, and means controlled by said first valve for initiating operation of said timing means when said capacitor potential rises above said preselected value.

ROBERT W. PEARSON.
DONALD P. FAULK.