July 16, 1935. J. W. DAWSON 2,008,413

ELECTRIC DISCHARGE APPARATUS

Filed Jan. 23, 1934

Fig. 1.

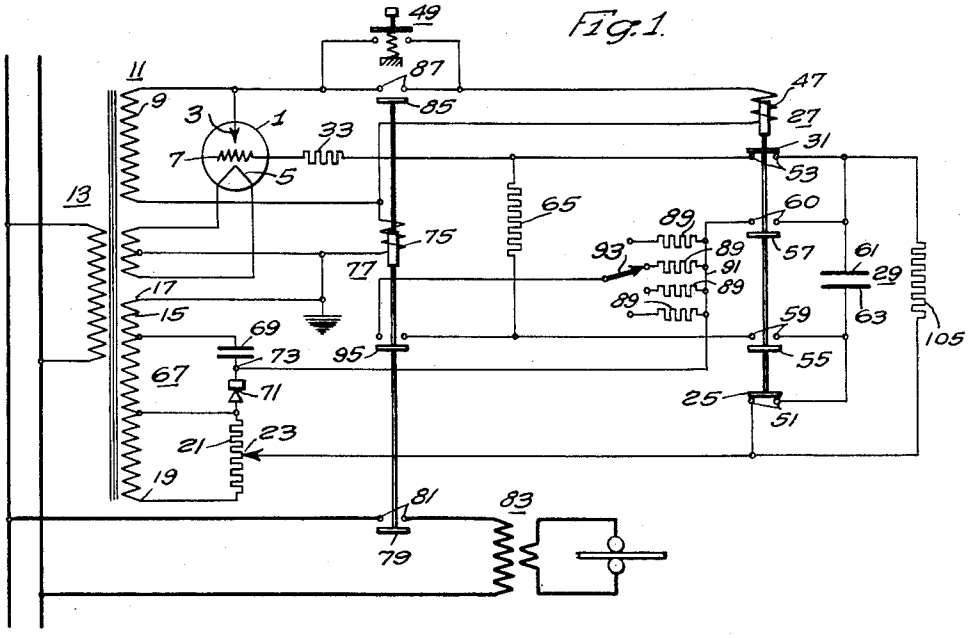


Fig. 2.

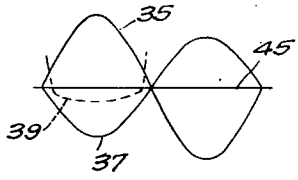


Fig. 3.

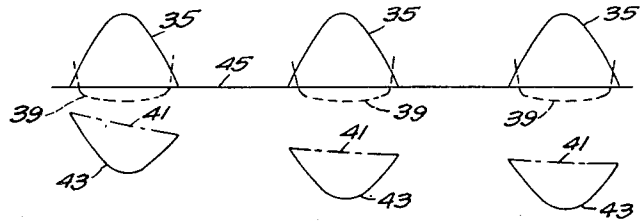


Fig. 4.

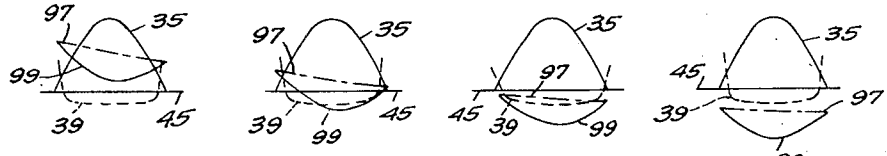
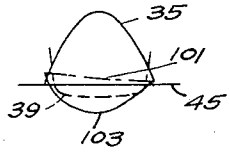


Fig. 5.



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ELECTRIC DISCHARGE APPARATUS

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Application January 23, 1934, Serial No. 707,931

17 Claims. (Cl. 175—320)

My invention relates to electric discharge apparatus and it has particular relation to apparatus for timing the operation of a work system.

It is an object of my invention to provide simple and inexpensive apparatus for timing the excitation of a work system.

Another object of my invention is to provide apparatus for controlling the state of excitation of a work system in such manner that the system may be energized when desired and will remain in energized condition when so energized for an accurately determinable interval of time.

A further object of my invention is to provide apparatus for controlling the operation of a work system of a type that shall maintain the system in operating condition after the operation is initiated for intervals of time that may be predetermined at the option of the operator.

Still another object of my invention is to provide timing apparatus for controlling the operation of a system of a type that shall be capable of maintaining the system in operation for any desired length of time within the limitations of the mechanical and electrical elements of the apparatus and the system.

An incidental object of my invention is to provide a simple and tractable electronic time delay relay.

Another incidental object of my invention is to provide a time delay relay operative by electrical power the timing periods of which shall be independent of the variations of potential supplied thereto.

More concisely stated, it is an object of my invention to provide translating apparatus for controlling a work system in such manner that it shall be capable of being energized by a simple operation and locked in in its energized condition for a predetermined interval of time after which it shall be automatically deenergized and the translating apparatus reverted to a condition wherein it may again be operated.

According to my invention, I provide a translating system incorporating an electric discharge device having a control electrode and a plurality of principal electrodes. One of the principal electrodes is of such character that the electrical conductive path between it and the control electrode has asymmetric properties. A capacitor is connected in the circuit of the last named principal electrode and the control electrode and is so charged through the conductive path between the electrodes that by reason of the resultant potential impressed between the electrodes the electric discharge device is maintained in a deenergized condition. The connections between the plates of the capacitor and the electrodes of the electric discharge device are reversed when it becomes necessary to operate the system. By reason of the resultant reversal of potential impressed between the electrodes of the electric discharge device, that are associated with the capacitor the electric discharge device becomes energized and the translating system is energized.

A translating system constructed in accordance with my invention has, of course, wide general applicability. It might for example be utilized for controlling the initiation and the timing of the steps in the processing of materials. In such apparatus contrivances may be provided whereby the completion of one step in a process causes the actuation of timing apparatus, constructed in accordance with my invention, which in turn initiates and maintains a subsequent step in the process. I have found, however, that my invention has particular applicability to welding systems and in the present instance my invention will be described herein as applied to an electrical welding system.

The novel features that I consider characteristic of my 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 showing a system constructed in accordance with my invention,

Fig. 2 is a graph showing the initial relationship between the potentials impressed between certain of the elements of the system,

Fig. 3 is a graph showing the relationship between the potentials impressed between the same elements when the system is in deenergized condition,

Fig. 4 is a graph showing the relationship between the potentials when the system is energized, and

Fig. 5 is a graph illustrating a condition which might exist if certain features incorporated in the preferred embodiment of my invention were not utilized.

The apparatus shown in Fig. 1 comprises an electric discharge device 1 having an anode 3, a cathode 5 and a control electrode 7. The electric discharge device 1 may be of the high vacuum or gas filled type. It is, however, preferably of the gas filled type, and I have found that a grid

glow tube capable of delivering continuously approximately ½ ampere may with advantage be utilized. Again it is to be noted that the electric discharge device 1 may be of the hot cathode or the cold cathode type. Thus a suitable grid controlled mercury pool tube or a grid-controlled tube of the Ignitron type may with advantage be utilized. However, in the preferred practice of my invention a hot cathode electric discharge device is utilized.

A suitable alternating potential is impressed between the anode 3 and the cathode 5 of the electric discharge device 1 from a section 9 of the secondary 11 of a power supply transformer 13. The transformer 13 is provided with an additional secondary section 15, one terminal 17 of which is connected to the cathode 5 of the electric discharge device 1. The latter section 15 is so arranged with respect to the section 9, whereby alternating potential is supplied to the principal electrodes 3 and 5 of the electric discharge device 1, that the remaining terminal 19 thereof is at a potential relative to the cathode 5 which is of opposite phase to the potential of the anode 3 relative to the cathode. A potentiometer 21 is connected across a plurality of windings of the section 15. The movable tap 23 of the potentiometer is coupled to the control electrode 7 of the electric discharge device 1 through a movable contactor 25 of a normally deenergized relay 27, a capacitor 29, another movable contactor 31 of the relay and a resistor 33 of comparatively low magnitude (1000 ohms in the usual practice of my invention).

It will be of advantage in the present instance to define the potential impressed between the control electrode 7 and the cathode 5 of the electric discharge device 1 as the control potential and the potential impressed between the anode 3 and the cathode 5 as the principal potential. The cathode may be regarded as at zero potential.

It is to be noted that the control potential in the present instance is in opposite phase to the principal potential. This condition is illustrated graphically in Fig. 2. In this view, the principal potential is represented by a sine curve 35 and the control potential is represented by a second sine curve 37 displaced in phase by 180° with respect to the first sine curve. If the electric discharge device 1 is of the gas filled type, it has an abrupt characteristic and when the control potential is below a limiting value for any particular value of principal potential, the electric discharge device is deenergized. When the control potential rises above the limiting control potential value, the electric discharge device 1 becomes energized and remains energized in spite of further variations in the control potential so long as the principal potential is greater than that required to maintain a discharge between the principal electrodes. The limiting values of control potential for the principal potential represented by the curve 35 are represented in Fig. 2 by a broken line curve 39.

It is to be noted with reference to Fig. 2 that the control potential curve 37 does not cut the limiting control potential curve 39 and in a system corresponding to Fig. 2, the electric discharge device 1 will be in deenergized condition. Fig. 2 may be taken as representing the initial condition of the system shown in Fig. 1.

Attention is called to the second half cycle of operation as it is represented in Fig. 2. It is to be noted that during this half cycle the principal potential is negative while the control potential is positive. Under such circumstances the capacitor 29 in the control circuit of the electric discharge device 1 is charged by the low current which flows between the control electrode 7 and the cathode 5 of the electric discharge device by reason of the potential impressed between the latter electrodes. The charging circuit extends from the movable tap 23 of the potentiometer 21 through the movable contactor 25, the capacitor 29, the movable contactor 31, the resistor 33, the control electrode 7, the cathode 5 to the upper terminal 17 of the secondary section 15. Since the resistor 33 in series with the control electrode 7 and the cathode 5 is of low magnitude, the capacitor 29 is charged at a comparatively high rate.

The capacitor 29 is, of course, only charged during the intervals during which positive control potential is impressed on the electric discharge device 1. However, it is to be noted that the conductive path between the control electrode 7 and the cathode 5 of the electric discharge device is asymmetric and for this reason the capacitor is not discharged during the subsequent half cycles when the principal potential is positive and the control potential is negative.

The capacitor 29 is charged during the negative half cycles of principal potential until a stable condition is attained. When this condition is attained a negative direct current potential is impressed on the control electrode 7 and the electric discharge device 1 is maintained in deenergized condition. The magnitude of the negative potential thus impressed may be varied by varying the position of the movable tap 23 of the potentiometer 21.

The condition of the electric discharge device as the capacitor is charging and in its final charged condition is represented graphically in Fig. 3. In this view, a number of selected positive half waves of principal potential are represented by half sine curves 35 and the corresponding limiting control potential curves 39 are represented by broken line curves as in Fig. 2. The increasing negative direct-current potential of the capacitor 29 is represented by a dot-dash curve 41 and the resultant negative control potential, which is composed of the negative direct current potential of the capacitor 29 plus the alternating potential supplied by the section 15 of the secondary 11 through which the capacitor 29 is charged, is represented by full line curves 43 below the time axis 45. It is to be noted that in the third set of curves the direct-current potential curve 41 is substantially parallel to the time axis 45. This set of curves represents the condition of the system when the capacitor 29 is completely charged. By reason of the fact that the resistor 33 is of small magnitude this condition is attained in a short period of time.

The exciting coil 47 of the normally deenergized relay 27, through the movable contactors 25 and 31 of which the capacitor 29 is charged, is connected in a normally open circuit including the section 9 of the secondary 11 whereby principal potential is supplied to the electric discharge device 1 and a manually operable push-button switch 49 which is normally in open position. When the push-button switch 49 is operated, the exciting coil 47 of the relay 27 becomes energized and the normally closed movable contactors 25 and 31 are disengaged from their corresponding fixed contacts 51 and 53

while a plurality of normally open movable contactors 55 and 57 engage their corresponding fixed contacts 59 and 60.

By the disengagement of the former movable contactors 25 and 31 from the corresponding fixed contacts 51 and 53, the plate 61 of the capacitor 29 which is charged negative is disconnected from the control electrode 7 and the other plate 63 which is charged positive is disconnected from the movable tap 23 of the potential. By the engagement of the later movable contactors 55 and 57 with their corresponding fixed contacts 59 and 60, the positive plate 63 of the capacitor 29 is connected to the control electrode 7 through a high resistor 65 (preferably of the order of 10 megohms) and the above mentioned low resistor 33 while the negative plate 61 of the capacitor 29 is connected to a network 67 comprising an additional capacitor 69 and a rectifier 71 in series with each other at the junction point 73 of the rectifier and the capacitor. The rectifier 71 may be of any available type but is preferably of the copper-oxide type. The network 67 is connected across a plurality of windings of the section 15 of the secondary 11 whereby control potential is supplied.

The points to which the net work 67 is connected are at a lower absolute potential relative to the cathode 5 than the movable tap 23 of the potentiometer 21. By reason of the presence of the rectifier 71 in the network, the capacitor 69 is charged and maintained in charged condition. The rectifier 71 in the net work 67 is so connected to the capacitor 69 that the junction joint 73 to which the negative plate 61 of the capacitor 29 is connected is at a fixed negative potential relative to the cathode 5 of the electric discharge device 1 but the absolute value of this potential is less than the absolute value of the potential of the movable tap 23 of the potentiometer.

It is seen that by the excitation of the relay 27, the position of the capacitor 29 in the circuit of the control electrode 7 and the cathode 5 is reversed and a positive direct-current potential is impressed on the control electrode 7. The circuit now extends from the lower or positive plate 63 of the capacitor 29, through the movable contactor 55, the resistor 65, the control electrode 7, the cathode 5, the biasing capacitor 69, the junction point 73, the movable contactor 57 to the upper or negative plate 61 of the capacitor 29. On this potential a negative direct-current potential corresponding to the potential of the junction point 73 of the network 67 to which the capacitor 29 is now connected and an additional alternating potential of opposite polarity to the principal potential, corresponding to the windings of the secondary section 15 above the net work 67, are superimposed in view of the fact that the junction point 73 and the section 15 are in the above-described circuit. The points in the section 15 of the secondary 11 to which the network 67 is connected are so selected that the positive direct-current potential applied to the control electrode 7 is considerably greater in magnitude than the negative direct-current potential and the alternating potential superimposed on the positive direct-current potential and the electric discharge device 1 is, therefore, energized by the reversal of the position of the capacitor 29 in the circuit.

It is to be noted, moreover, that the capacitor 29 is now connected in the control circuit of the electric discharge device 1 through a high resistor 65 and by reason of the presence of the high resistor it is neither appreciably charged nor appreciably discharged through the conductive path comprising the control electrode 7 and the cathode 5.

One of the principal advantages which arises from my invention resides in the use of the normally asymmetric conducting path between the control electrode 7 and the cathode 5 for charging the capacitor 29. Since this path has the property of asymmetric conductivity the rectifier which would otherwise be necessary in the charging circuit is eliminated.

When the electric discharge device 1 is thus energized, the exciting coil 75 of a second relay 77 is energized. The energizing circuit for the relay extends from the upper terminal of the secondary section 9, through the anode 3, the cathode 5, the exciting coil 75 to the lower terminal of the secondary section 9. A movable contactor 79 of the relay engages a plurality of corresponding fixed contacts 81 and causes a work system 83, which may for example be a spot welding system as shown to become energized. A second movable contactor 85 of the last mentioned relay 77 engages a plurality of fixed contacts 87 shunting the push-button switch 49 and the circuit through the exciting coil 47 of the first-mentioned relay 27 is thus closed and the relay is energized independently of the push-button switch. Thus, by a single actuation of the push-button switch 49 the electric discharge device 1 is energized and the work system 83 is locked in in energized condition regardless of the subsequent opening of the push-button switch.

The period during which the work system 83 operates may be regulated by controlling the discharge of the capacitor 29. For this purpose a plurality of resistors 89 of the grid leak type are provided. The resistors 89 are of the order of several hundred thousand ohms and are all of different magnitude.

The resistors 89 are each connected at one terminal to a common conductor 91 which is in turn adapted to be connected to the negative plate 61 of the capacitor 29 by the normally-open contactor 57 of the relay 27 when the relay is energized. A movable contact element 93 is provided for the purpose of connecting the remaining terminals of each of the resistors 89 individually to the positive plate 63 of the capacitor 29. However, the contact element 93 can only be connected to the positive plate 63 through normally-open contactor 95 of the relay 77 and the remaining normally-open contactor 55 of the relay 27 both of which are in a series network with the contact element and the positive plate.

When the relay 47 is energized by the operation of the push-button switch 49, its normally-open movable contactors 55 and 57 are closed and the electric discharge device 1 is energized. The relay 77 is therefore, energized and a network including the normally-open movable contactor 57 of the former relay 27, one of the resistors 89, the movable contact element 93 of the resistor system, the movable contactor 95 of the latter relay 77, the remaining normally open contactor 55 of the former relay 27 and the capacitor 29 is closed and the capacitor is discharged at a rate depending on the magnitude of the particular resistor 89 connected across its terminals. The rate at which the capacitor is discharged is also dependent on the initial difference of potential impressed between the plates 61 and 63 of the capacitor 29 which is in turn dependent on the po-

sition of the movable tap 23 of the potentiometer 21. It is to be observed that while finite differences in the time of discharge of the capacitor 29 may be attained by varying the position of the movable contact element 93 from one resistor 89 to another, the adjustments of the time of discharge at values between the values attained by utilizing resistors of successive magnitudes may be attained by varying the position of the movable tap 23 of the potentiometer 21.

The function of the potentiometer in the system is of extreme importance for the reason that independent grid resistors must necessarily be utilized to attain appreciable times of discharge of the capacitor 29. On the other hand it is essential for the proper operation of a system of the type involved here that the time of operation of the apparatus be capable of any desired adjustment. To attain this flexibility in adjustment with resistors alone is out of the question since an inordinately large number of resistors would be required. The result is attained by utilizing the potentiometer in cooperation with the resistors.

Attention is also called to the fact that the capacitor 29 begins to discharge only after the relay 77 is energized. The work system 83 is also energized when this relay is energized and consequently the time required for the capacitor 29 to discharge, that is to say, the time during which the work system is energized begins to tally substantially at the instant that the work system 83 is energized.

The condition of the system during the interval during which the capacitor 29 is discharged is represented graphically in Fig. 4. In this view, the principal potential during a series of selected positive half cycles and the corresponding limiting control potential are represented as in the other views. The decay of the potential impressed on the capacitor 29 is represented by a dot-dash curve 97 which is, for most of the half cycles 35, above the time axis 45, since the position of the capacitor 29 in the circuit has been reversed. On this potential are super-imposed the negative potential provided by the network 67 and the alternating potential provided by the windings of the section 15 of the secondary 11 which are above the network and the resultant control potential is represented by the full line curves 99.

The function of the negative direct current potential provided by the network 67 can be seen by referring to Fig. 5. In this view a half-cycle of operation of a system in which the network 67 is omitted and the negative plate 61 of the capacitor 29 is directly connected to a point in the secondary section 15 through the movable contactor 57 of the relay 27, is represented.

The principal potential and limiting control potential are represented as in the other views. The decaying potential of the capacitor is represented by a dot-dash curve 101, and as it is shown it corresponds to a condition of the system in which the capacitor is substantially discharged. It is to be noted that the curve 101 approaches and is asymptotic to the time axis 45. The control potential is represented by a full line curve 103 which intersects the limiting control potential curve 39 near the end of the half cycle of potential.

As is apparent, the electric discharge device will become energized in the actual system represented by Fig. 5 near the end of its positive half cycle of principal potential. This condition occurs near the end of period of discharge of the capacitor and may persist for an indefinite period of time or even recur after the electric discharge device is deenergized depending on the random condition of the apparatus whereby power is supplied to the system. Moreover, the limiting control potential curve 39 of different electric discharge devices 1 may vary over a comparatively wide range, and the excitation of the device 1 near the end of the period of discharge of the capacitor may, therefore, become a matter of uncertainty.

Careful consideration of Fig. 5 will reveal that the difficulty arises by reason of the fact that the discharge curve 101 of the capacitor is asymptotic to the time axis which is in turn above the limiting control potential curve 39 to a considerable extent. Since in the discharged condition of the capacitor the curve 101 is substantially identical with the time axis 45 the reversion of a system of the type represented in Fig. 5 to a deenergized condition must depend on the application of negative half cycles of alternating potential which are necessarily of uncertain form. For this reason the negative direct current potential of the network 67 is superimposed on the positive potential. The negative potential is of considerably greater magnitude than the most negative value of the limiting control potential and the corresponding discharge curve 97 is therefore asymptotic to the line parallel to the time axis 45 but well below the limiting control potential curve 39. In the region of the limiting control potential curve it has a marked negative slope (as shown in Fig. 4) and the half cycles during which the limiting control potential curve 39 are intersected by the control potential curve 99 are therefore sharply separated from each other.

After the electric discharge device 1 is deenergized, the relay 77 is deenergized, the movable contactor 85 connected across the push-button switch 49 is disengaged from its corresponding fixed contacts 87 and the relay 27 is deenergized. The normally-open movable contactors 55 and 57 are, therefore, disengaged from their corresponding fixed contacts 59 and 60 and the normally-closed movable contactors 25 and 31 are engaged with their corresponding fixed contacts 51 and 53. The system is thus reverted to its initial condition.

Of particular importance in the application of my system to timing is the fact that the timing periods determined by the decay of charge on the capacitor is substantially independent of potential variations in the source of supply of energy. It is to be noted that the functioning of the system depends on the decrease of the potential impressed between the plates 61 and 63 of the capacitor 29 below the negative direct-current potential provided by the network 67. If variation of a predetermined percent occurs in the potential of the power supply the potential impressed between the plates 61 and 63 of the capacitor 29 will be varied correspondingly and as the potential decays it will maintain the percent of variation of the value which it would have if the variation had not occurred. On the other hand the absolute value of the direct-current potential supplied by the network 67 will also be varied in the same manner. The electric discharge devices utilized in the preferred practice of my invention have a maximum value of limiting control potential which is of the order of two or three negative volts and for all practical purposes the electric discharge device may be regarded as being deenergized, (and the timing pe-

riod may be regarded as at an end) substantially at the point at which the potential impressed on the capacitor **29** is equal to the negative potential provided by the network **67**. Since, however, the per cent variation of the former in a positive sense is equal to the per cent of variation of the latter in the negative sense the net effect of the variation on the timing is nil.

Since the capacitor **29** connected in the control circuit of the electric discharge device **1** may be charged to a dangerously high difference of potential before the system is taken out of use, a resistor **105** of comparatively large magnitude (preferably of the order of 700,000 ohms) is connected across the plates **61** and **63** of the capacitor through one of the normally-closed contactors **25** of the relay **27**. The resistor **105** discharges the capacitor when the system is disconnected from the power source. On the other hand, when the system is in use, the resistor **105** is of such large magnitude compared to the resistor **33** through which the capacitor **29** is charged that it does not disturb the charging operation. Moreover, the resistor **105** does not disturb the discharging operation when the system is in use because the relay **27** is then energized and it is disconnected from the capacitor **29**.

My invention has herein been described as embodied in a particular system. It is apparent that numerous changes may be made in the system. One of the most apparent modifications which may arise involves the section **15** of the secondary **11** through which potential is supplied to the control circuit of the electric discharge device **1**. In the preferred practice of my invention as it has been explained hereinabove, an electric discharge device having a so-called negative characteristic is utilized. A mercury-vapor-filled hot-cathode grid-glow tube is an example of such an electric discharge device. Such a device has a limiting control potential curve which has negative values for normal values of positive principal potential.

Although I have shown and described certain specific embodiments of my invention, I am fully aware that many modifications thereof are possible. My invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and by the spirit of the appended claims.

I claim as my invention:

1. Translating apparatus comprising an electric discharge device having a control electrode and a plurality of principal electrodes, means for impressing alternating potentials between said principal electrodes and between said control electrode and one of said principal electrodes, a capacitor coupled between said control electrode and said last-named principal electrode, whereby said capacitor is charged by the flow of current between said control electrode and said last-named principal electrodes and a predetermined direct current potential is impressed between said control electrode and said last-named principal electrode and means for reversing the coupling between said capacitor and said control electrode and said last-named principal electrode whereby the polarity of the direct-current potential impressed between said control electrode and said last-named principal electrode is reversed.

2. Translating apparatus comprising an electric discharge device having a control electrode and a plurality of principal electrodes, the properties of said control electrode and one of said principal electrodes being such that the conductive path between said last-named electrodes is asymmetric, means for impressing alternating potentials between said principal electrodes and between said control electrode and the principal electrode with which it forms an asymmetric path, a capacitor coupled between said last-named electrodes, whereby said capacitor is charged by the current flow between said last-named electrodes and a predetermined direct-current potential is impressed between said last-named electrodes and means for reversing the coupling between said capacitor and said last-named electrodes, whereby the polarity of the direct-current potential impressed between said last-named electrodes is reversed.

3. Translating apparatus comprising an electric discharge device having a control electrode and a plurality of principal electrodes, the properties of said control electrode and one of said principal electrodes being such that the conductive path between said last-named electrodes is asymmetric, means for impressing alternating potentials between said principal electrodes and between said control electrode and the principal electrode with which it forms an asymmetric path, a capacitor, means including a resistor of relatively low magnitude for connecting said capacitor between said last-named electrodes, whereby said capacitor is charged by the current flow between said last-named electrodes and a predetermined direct-current potential is impressed between said last-named electrodes and means for reversing the connections between said capacitor and said last-named electrodes, whereby the polarity of the direct-current potential impressed between said last-named electrodes is reversed.

4. Translating apparatus comprising an electric discharge device having a control electrode and a plurality of principal electrodes, the properties of said control electrode and one of said principal electrodes being such that the conductive path between said last-named electrodes is asymmetric, means for impressing alternating potentials between said principal electrodes, a capacitor, a supply of alternating potential one terminal of which is connected to the principal electrode between which and the control electrode the conductive path is asymmetric, means, including a resistor of low magnitude, for connecting said capacitor between said control electrode and the other terminal of said potential supply, whereby said capacitor is charged by the current flow between said last-named electrodes and a predetermined direct-current potential is impressed between said last-named electrodes, and means for reversing the connections between said capacitor and said control electrode said last-named terminal of said potential supply, whereby the polarity of the direct-current potential impressed between said last-named electrodes is reversed.

5. Translating apparatus comprising an electric discharge device having a control electrode and a plurality of principal electrodes, the properties of said control electrode and one of said principal electrodes being such that the conductive path between said last-named electrodes is asymmetric, means for impressing alternating potentials between said principal electrodes, a capacitor, a supply of alternating potential one terminal of which is connected to the principal electrode between which and the control electrode the conductive path is asymmetric, means including a resistor of low magnitude, for con-

necting said capacitor between said control electrode and the other terminal of said potential supply, whereby said capacitor is charged by the current flow between said last-named electrodes and a predetermined direct-current potential is impressed between said last-named electrodes, a resistor of high magnitude and means for reversing the connections between said capacitor and said control electrode said last-named terminal of said potential supply and for connecting said last-named resistor in series with said capacitor and the asymmetrically conductive path between said last-named electrodes, whereby the polarity of the direct-current potential impressed between said last-named electrodes is reversed.

6. Translating apparatus comprising an electric discharge device having a control elcctrode and a plurality of principal electrodes, the properties of said control electrode and one of said principal electrodes being such that the conductive path between said last-named electrodes is asymmetric, means for impressing alternating potentials between said principal electrodes, a capacitor, a supply of alternating potential one terminal of which is connected to the principal electrode between which and the control electrode, the conductive path is asymmetric, means including a resistor of low magnitude, for connecting said capacitor between said control electrode and the other terminal of said potential supply, whereby said capacitor is charged by the current flow between said last-named electrodes and a predetermined direct-current potential is impressed between said last-named electrodes, a resistor of high magnitude, means for reversing the connections between said capacitor, said control electrode and said last named terminal of said potential supply and for connecting said last-named resistor in series with said capacitor and the asymmetrically conductive path between said last-named electrodes, whereby the polarity of the direct-current potential impressed between said last-named electrodes is reversed and means for discharging said capacitor at a predetermined rate after said connections have been so reversed.

7. Translating apparatus comprising an electric discharge device having a control electrode and a plurality of principal electrodes, the properties of said control electrode and one of said principal electrodes being such that the conductive path between said last-named electrodes is asymmetric, means for impressing alternating potentials between said principal electrodes, a capacitor, a supply of alternating potential one terminal of which is connected to the principal electrode between which and the control electrode, the conductive path is asymmetric, means including a resistor of low magnitude, for connecting said capacitor between said control electrode and the other terminal of said potential supply, whereby said capacitor is charged by the current flow between said last-named electrodes and a predetermined direct-current potential is impressed between said last-named electrodes, a resistor of high magnitude, means for reversing the connections between said capacitor, said control electrode and said last-named terminal of said potential supply and for connecting said last-named resistor in series with said capacitor and the asymmetrically conductive path between said last-named electrodes, whereby the polarity of the direct-current potential impressed between said last-named electrodes is reversed and means for discharging said capacitor at a predetermined rate after said connections have been so reversed, said means including a plurality of independent resistors, said last-named resistors having different magnitudes and means for connecting any one of said resistors in the circuit of said capacitor.

8. Translating apparatus comprising an electric discharge device having a control electrode and a plurality of principal electrodes, the properties of said control electrode and one of said principal electrodes being such that the conductive path between said last-named electrodes is asymmetric, means for impressing alternating potentials between said principal electrodes, a capacitor, a supply of alternating potential one terminal of which is connected to the principal electrode between which and the control electrode the conductive path is asymmetric, means including a resistor of low magnitude, for connecting said capacitor between said control electrode and the other terminal of said potential supply, whereby said capacitor is charged by the current flow between said last-named electrodes and a predetermined direct-current potential is impressed between said last-named electrodes, a resistor of high magnitude, means for reversing the connections between said capacitor, said control electrode and said last-named terminal of said potential supply and for connecting said last-named resistor in series with said capacitor and the asymmetrically conductive path between said last-named electrodes, whereby the polarity of the direct-current potential impressed between said last-named electrodes is reversed, means for discharging said capacitor at a predetermined rate after said connections have been so reversed, said means including a plurality of independent resistors, said last named resistors having different magnitudes, and means for connecting any one of said resistors in the circuit of said capacitor and means for varying the magnitude of said direct-current potential impressed between said last-named electrodes thereby to attain times of discharge of said capacitor that lie between the times attained by connecting any two of said last-named resistors in the circuit of said capacitor.

9. Translating apparatus comprising an electric discharge device having an anode, a cathode and a control electrode, means for impressing an alternating potential between said anode and cathode, a capacitor, a source of alternating potential, means for connecting said capacitor in series with said control electrode and said cathode means for so connecting said source to the network including said capacitor and said control electrode and said cathode that the potentials impressed between said control electrode and said cathode are in opposite phase to the potentials impressed between said anode and said cathode, whereby said capacitor is charged and a direct-current negative potential is impressed between said control electrode and said cathode to maintain the current between said anode and said cathode low and means for reversing the connections of said capacitor in said network whereby a positive potential is impressed between said control electrode and said cathode and substantial current is transmitted between said anode and said cathode.

10. Translating apparatus comprising an electric discharge device having an anode, a cathode and a control olectrode, means for impressing an alternating potential between said anode

and cathode, a capacitor, a source of alternating potential, means for connecting said capacitor in series with said control electrode and said cathode, means for so connecting said source to the network including said capacitor and said control electrode and said cathode that potentials impressed between said control electrode and said cathode are in opposite phase to the potentials impressed between said anode and said cathode, whereby said capacitor is charged and a direct-current negative potential is impressed between said control electrode and said cathode to maintain the current between said anode and said cathode low, means for reversing the connections of said capacitor in said network whereby a positive potential is impressed between said control electrode and said cathode and substantial current is transmitted between said anode and said cathode and means for superimposing on said positive potential a negative potential of absolute value substantially smaller than said positive potential.

11. Timing apparatus comprising an electric discharge device having a control electrode and a plurality of principal electrodes, means for impressing potentials between said principal electrodes and between said control electrode and one of said principal electrodes that are of such relative magnitudes and polarities that said electric discharge device is maintained in substantially deenergized condition, current responsive means, for reversing the polarity of the potential impressed between said control electrode and said last-named principal electrode, whereby said electric discharge device is energized, means for providing an impulse of current to temporarily actuate said current responsive means to reverse the polarity of the potential impressed between said control electrode and said last-named principal electrode and means to be actuated by said electric discharge device when it is energized and to remain so actuated only so long as said electric discharge device remains energized for maintaining said current responsive means in actuated condition as long as said electric discharge device remains energized.

12. Timing apparatus comprising an electric discharge device having a control electrode and a plurality of principal electrodes, means including a capacitor to be charged to a predetermined potential difference for impressing potentials between said principal electrodes and between said control electrode and one of said principal electrodes that are of such relative magnitudes and polarities that said electric discharge device is maintained in substantially deenergized condition, current responsive means for reversing the connections of said capacitor thereby to reverse the polarity of the potential impressed between said control electrode and said last-named principal electrode, whereby said electric discharge device is energized, means for providing an impulse of current to temporarily actuate said current responsive means to reverse the polarity of the potential impressed between said control electrode and said last-named principal electrode and means to be actuated by said electric discharge device when it is energized and to remain so actuated only so long as said electric discharge device remains energized for maintaining said current responsive means in actuated condition as long as said electric discharge device remains energized and means to be actuated by said electric discharge device after it is energized to discharge said capacitor.

13. Translating apparatus comprising an electric discharge device having a control electrode and a plurality of principal electrodes, the properties of said control electrode and one of said principal electrodes being such that the conductive path between said last-named electrodes is asymmetric, means for impressing alternating potentials between said principal electrodes, a capacitor, a supply of alternating potential one terminal of which is connected to the principal electrode between which and the control electrode, the conductive path is asymmetric, means including a resistor of low magnitude, for connecting said capacitor between said control electrode and the other terminal of said potential supply, whereby said capacitor is charged by the current flow between said last-named electrodes and a predetermined direct-current potential is impressed between said last-named electrodes, a resistor of high magnitude, means for reversing the connections between said capacitor, said control electrode and said last-named terminal of said potential supply and for connecting said last-named resistor in series with said capacitor and the asymmetrically conductive path between said last-named electrodes, whereby the polarity of the direct-current potential impressed between said last-named electrodes is reversed and means for discharging said capacitor at a predetermined rate after said connections have been so reversed, said means including resistance means to be connected in the circuit of said capacitor and means for varying the magnitude of the resistance of said resistance means in finite discontinuous steps.

14. Translating apparatus comprising an electric discharge device having a control electrode and a plurality of principal electrodes, the properties of said control electrode and one of said principal electrodes being such that the conductive path between said last-named electrodes is asymmetric, means for impressing alternating potentials between said principal electrodes, a capacitor, a supply of alternating potential one terminal of which is connected to the principal electrode between which and the control electrode the conductive path is asymmetric, means including a resistor of low magnitude, for connecting said capacitor between said control electrode and the other terminal of said potential supply, whereby said capacitor is charged by the current flow between said last-named electrodes and a predetermined direct-current potential is impressed between said last-named electrodes, a resistor of high magnitude, means for reversing the connections between said capacitor, said control electrode and said last-named terminal of said potential supply and for connecting said last-named resistor in series with said capacitor and the asymmetrically conductive path between said last-named electrodes, whereby the polarity of the direct-current potential impressed between said last-named electrodes is reversed, means for discharging said capacitor at a predetermined rate after said connections have been so reversed, said means including resistance means to be connected in the circuit of said capacitor and means for varying the magnitude of the resistance of said resistance means in finite discontinuous steps and means for varying the magnitude of said direct-current potential impressed between said last-named electrodes thereby to attain times of discharge of said capacitor that lie between the

times attained by varying said resistance discontinuously from one value to another.

15. Translating apparatus comprising an electric discharge device having an anode, a cathode and a control electrode, means for impressing an alternating potential between said anode and cathode, a capacitor, a source of alternating potential, means for connecting said capacitor in series with said control electrode and said cathode means for so connecting said source to the network including said capacitor and said control electrode and said cathode that the potentials impressed between said control electrode and said cathode are out of phase to the potentials impressed between said anode and said cathode, whereby said capacitor is charged and a direct-current negative potential is impressed between said control electrode and said cathode to maintain the current between said anode and said cathode low and means for reversing the connections of said capacitor in said network whereby a positive potential is impressed between said control electrode and said cathode and substantial current is transmitted between said anode and said cathode.

16. In combination a capacitor, means for charging said capacitor to values of difference of potential that may be varied continuously from a predetermined minimum value to a predetermined maximum value and resistance means, the magnitude of the resistance of which may be varied in discontinuous steps from a predetermined maximum to a predetermined minimum value, for discharging said capacitor.

17. Translating apparatus comprising an electric discharge device having an anode, a cathode and a control electrode, means for impressing an alternating potential between said anode and cathode, a capacitor, a source of alternating potential, means for connecting said capacitor in series with said control electrode and said cathode, means for so connecting said source to the network including said capacitor and said control electrode and said cathode that potentials impressed between said control electrode and said cathode are in opposite phase to the potentials impressed between said anode and said cathode, whereby said capacitor is charged and a direct-current negative potential is impressed between said control electrode and said cathode to maintain the current between said anode and said cathode low, means for reversing the connections of said capacitor in said network whereby a positive potential is impressed between said control electrode and said cathode and substantial current is transmitted between said anode and said cathode and means for superimposing on said positive potential a negative potential of absolute value substantially smaller than said positive potential but of such magnitude that the potential impressed between said control electrode and said cathode attains a value sufficient to cause said electric discharge device to be deenergized while the rate of decay of the potential impressed on said capacitor has a considerable value.

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