

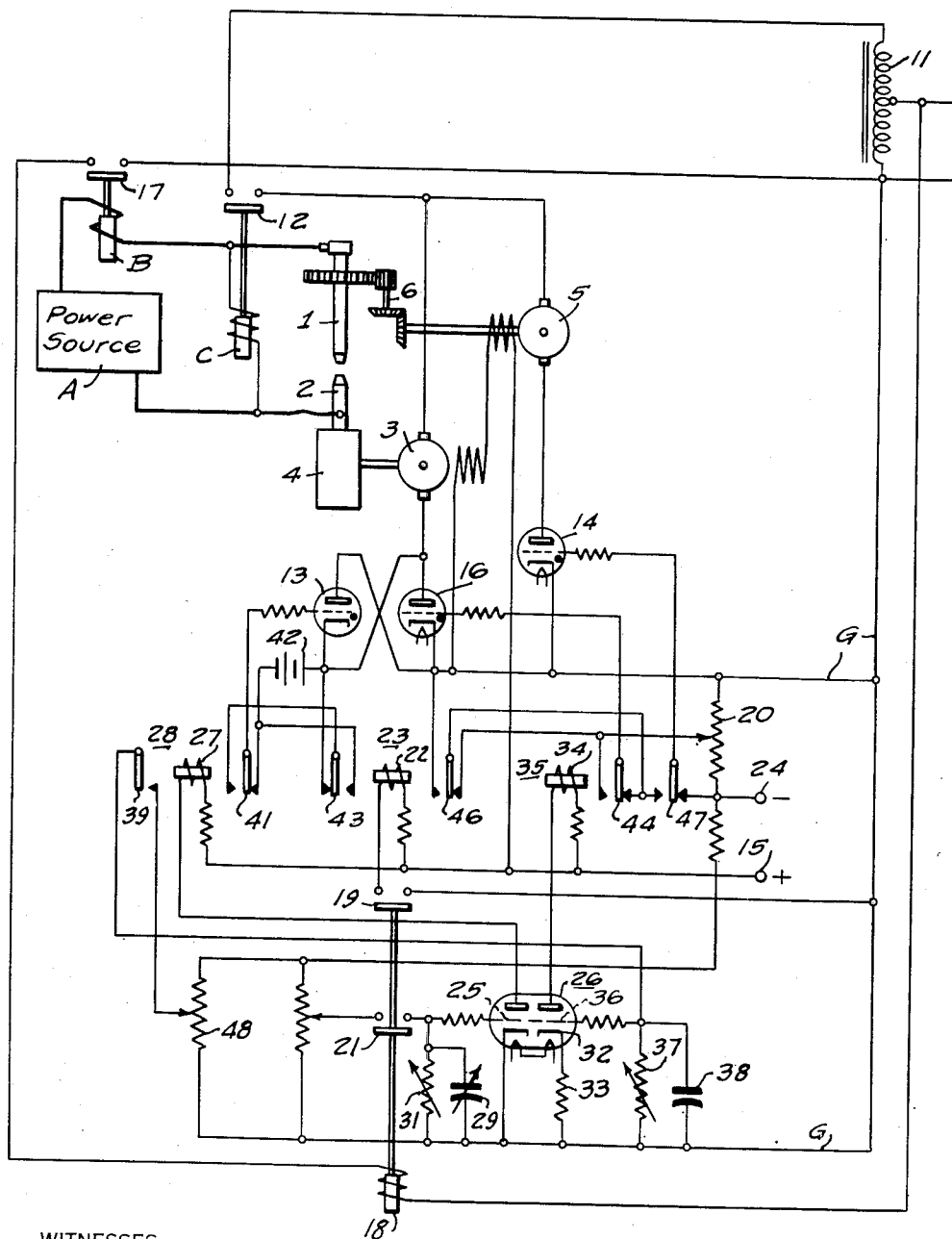
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CONTROL OF ARCING ELECTRODES

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WITNESSES:

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CONTROL OF ARCING ELECTRODES

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My invention relates to systems for automatically controlling electrodes of an electric arc, and in particular relates to a system in which the electrodes of such an arc are first moved together until they make contact, then moved apart for a predetermined travel, and then one of the electrodes is continuously rotated about its axis as long as the arc continues to burn. Where it is desired to operate an arc between solid electrodes in a chamber which is continually evacuated to a low pressure, the arc, after being struck, is found to be in a relatively unstable condition in the case of many electrode materials, so that it is necessary to repeatedly restrike it to produce long continued operation. The present arrangement is particularly adapted to thus strike, and when necessary, repeatedly restrike such an arc.

One object of my invention is, accordingly, to provide an automatically controlled arrangement in which a pair of electrodes between which an arc is to be operated are first moved together, then separated from each other by a predetermined travel, and then one electrode is continuously rotated to insure an even consumption of the electrode material over its surface.

Another object of my invention is to provide an arc control system of the type which is described, in which the restriking of the arc is postponed for a predetermined interval after it becomes extinguished in order to permit the electrodes to cool sufficiently so that they will not weld together when moved into contact with each other.

Still another object of my invention is to provide a system in which a pair of arc electrodes are moved into contact and then out of contact by an electric motor which is automatically controlled to carry out such movements by a relay system.

A further object of my invention is to provide a system of control in which a pair of electrodes is first moved into contact and then moved out of contact by one motor controlled automatically in response to the electrical condition of the arc, and then a second motor is controlled so as to rotate one of the electrodes continuously as long as the arc continues to burn, the last-mentioned motor being then deenergized and the first-mentioned motor being caused to restrike the arc at the end of the present cooling period by carrying out its above-described sequence of operations again.

A still further object of my invention is to provide a motor control system of the nature above-described in which relays responding to the elec-

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trical condition of the arc merely control the grid potential of electrical discharge tubes carrying larger currents than the relay contacts to thereby avoid difficulty from arcing and wear of such contacts.

Other objects of my invention will become apparent upon reading the following description, taken in connection with the drawing, in which the single figure is a schematic circuit diagram showing the motor, relay and control tube connections capable of carrying out my invention.

Referring in detail to the drawing, an upper electrode 1 and a lower electrode 2 of any desired materials are arranged in axial alignment so that their ends can be moved into contact and separated to draw an electric arc between them. Said arc is supplied with power from a source A in series with a "current flowing" relay B having normally open contacts closed when current flows from said source A. The electrode 2 is supported by any suitable arrangement, of which numerous examples are known to men skilled in the art, so that it can be moved vertically to make contact with the electrode 1 by rotating a motor armature 3 connected to it by a suitable mechanism 4. Rotation of the armature 3 in one direction raises the electrode 2 and in the opposite direction lowers it. The electrode 1 is similarly supported so that it can be rotated about its axis by the armature 5 of a turning motor through a suitable mechanical linkage 6, which is indicated only schematically in the drawing.

My invention relates to the system of electrical control for turning the armatures 3 and 5 in response to electrical condition in the circuit supplying the electrodes 1 and 2 to carry out in sequence the operation of moving the electrode 2 upward into contact with electrode 1, and then moving it downward for a predetermined travel away from electrode 1; and, upon attainment of this predetermined travel, stopping the armature 3 and starting the armature 5 into rotation to continuously turn the electrode 1 until current flow through the arc ceases. The control system thereupon, after a predetermined interval, again starts the armature 3 into rotation to repeat the above-described program of operations whenever the arc goes out.

Turning in more detail to the drawing, power for operation of the armatures 3 and 5 and the control system therefor is furnished by a transformer 11, having its input terminals connected to an ordinary alternating-current supply line. A suitable relay C which may be connected across the electrodes 1 and 2 is arranged to close a pair

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of contacts 12 to close the circuit from one terminal of the transformer to the upper brushes (as they appear in the drawing) bearing on the commutator of each of the armatures 3 and 5. The lower brush for the armature 3 is connected to the cathode terminal of a grid controlled gaseous discharge tube 13, having its anode connected to a common bus G running to the other side of the transformer 11, and is also connected to the plate of tube 16. The lower brush for the armature 5 is connected to the anode of a second grid controlled gaseous electrical discharge tube 14, having its cathode connected to the bus G. The tubes 13, 14 and 16 being unilaterally conductive, it is obvious that the current flowing through armatures 3 and 5 will be direct current, provided (as is herein arranged) that only 13 or 16 is conducting at any time. The field windings associated with the armatures 3 and 5 are connected in series with each other, one terminal thereof being connected to the bus G and the other terminal being connected to the positive terminal 15 of a direct-current voltage source, having its negative terminal connected to said bus. The anode and cathode of the tube 13 are connected, respectively, to the cathode and anode of a third grid control gaseous discharge tube 16.

In serial relation with the current flowing through the electrodes 1 and 2, there is provided a "current flowing" relay B having a pair of contacts 17 which are open when the said current is zero and are maintained closed as long as a comparatively small current flows through said electrodes. The relay contacts 17 are connected to energize the closing winding of a relay 18 which maintains two pairs of contacts 19 and 21 in open-circuit condition as long as the winding 18 is deenergized, but closes contacts 19 and 21 as long as relay winding 18 is energized.

The contacts 19 are arranged to energize by their closure the actuating winding 22 of a relay 23, having two sets of contacts which are moved from closed to open position when the winding 22 is energized and two additional sets of contacts which are moved from open to closed condition when said winding 22 is energized. The relay 23 and all other relays are shown in the drawing in the condition they stand in when their actuating windings are deenergized. The functions of the sets of contacts just mentioned will be more fully described later.

The contacts 21 of the relay 18 are arranged to impress, when they are closed, negative voltage derived from a bias voltage source, having a terminal 24 which is maintained at a negative potential relative to the above-mentioned bus G, upon the control electrode 25 of a double triode tube 26, which has a cathode connected to said bus G and has its anode connected in series with the energizing winding 27 of a relay 28, drawing current for such purposes from the positive terminal 15 above-mentioned. Between the control electrode 25 of the double triode 26 and the common bus is connected a variable capacitor 29 and a variable resistor 31 in multiple with each other. It will be evident from these connections that, when the relay 18 is deenergized, the control electrode 25 acquires the same potential as its associated cathode, i. e., the potential of the common bus; but that as soon as the relay 18 is energized, the contacts 21 are closed to impress across the capacitor 29 a negative potential, and as soon as the charge is built up sufficiently, the same negative potential is impressed on the control electrode 25 relative to its associated

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cathode. On the other hand, when, at some subsequent time, the relay 18 is deenergized, thereby opening the contacts 21, the capacitor 29 slowly discharges through the resistor 31 and thereby gradually removes the negative potential from the control electrode 25 thus permitting current flow through the winding 27 to begin after a time delay which may be varied at will by adjusting the variable resistor 31 or the variable capacitor 29.

The double triode 26 likewise has a second cathode 32 connected to the common bus through a resistor 33 and has an anode connected to an actuating winding 34 of a third relay 35, drawing current for this purpose from the positive terminal 15 above-mentioned. Associated with the cathode 32 is a control electrode 36 which is connected to the bus G through a variable resistor 37 shunted by a capacitor 38. The control electrode 36 is likewise connected to a movable switch member 39 in the relay 28 for purposes which will be more fully explained later.

The control electrode of the tube 13 is connected to a movable element 41 in the relay 27 which is adapted, in the deenergized condition of winding 27, to make contact with a line running to the negative terminal of a bias battery 42 having a positive terminal connected to the cathode of the above-mentioned tube 13. In the energized condition of winding 27, the switch member 41 connects the control electrode of tube 13 to a movable switch member 43 in the relay 23.

The control electrode of the tube 16 is connected to a movable switch member 44 in the relay 35, which switch member in the deenergized condition of the latter relay is connected to a movable member 46 in the relay 23. In the deenergized condition of the winding 22, the movable member 46 is connected to the negative terminal 24 of the bias source above-mentioned by way of a potential divider 20.

The control electrode of the tube 14 is connected to a movable switch member 47 in the relay 35, which switch member in the deenergized condition of the winding 34 of said relay is connected to draw bias from the negative bias terminal 24 above-mentioned.

The movable switch member 46 in the relay 23 is arranged, in the energized condition of the actuating winding 22 of the latter, to make contact with the bus G. The movable switch member 43 in said relay is arranged under the same conditions to make contact with the negative terminal of the bias battery 42. The movable member 39 of the relay 28 is arranged in the energized condition of the actuating winding 27 of the latter to make contact through a potential divider 48 with the negative bias terminal 24 above-mentioned. The movable switch member 41 of the same relay is arranged to make contact with the movable switch member 43 of the relay 23 under the same conditions. The movable member 47 of the relay 35 is arranged to make contact when the actuating winding 34 thereof is energized with the movable switch member 46 of the relay 23, and the movable switch member 44 in relay 35 is arranged to make contact under the same condition with the potential divider 20 above-mentioned.

Such being the electrical connections of the control system for armatures 3 and 5, the mode of operation of the system is as follows.

Starting with the electrodes 1 and 2 separated from each other, and the primary winding of transformer 11 connected to power source appli-

oation of voltage to electrodes 1 and 2 from power source A causes the closure of the relay contacts 12 to impress the voltage of the transformer 11 on the upper brushes of the armatures 3 and 5. Since, in their separated condition, no current will flow across the gap between the electrodes 1 and 2, the contacts 17 of the "current flowing" relay B remain open and the relay 18 stands deenergized. The contacts 21 of the latter are thus separated so that no negative voltage is impressed from the bias source 24 on the control electrode 25 in double triode 26, but that control electrode has acquired the potential of its cathode through the previous discharge of capacitor 28 through resistor 31. Under such conditions, current flow readily takes place between the anode and cathode associated with control electrode 26, and actuates winding 27 of relay 28 by current flow from the positive terminal 15. The switch members 44 and 49 of relay 28 thus stand in their respective left-hand and right-hand positions whenever the input terminals of transformer 11 are energized, and stay so as long as no current flows through electrodes 1 and 2. The movable switch member 41 of relay 28 is, accordingly, held in its left-hand position to connect the control electrode of the tube 13 to the movable switch member 43 in the relay 23.

By reason of the fact that the relay 18 is deenergized, the contacts 19 are open and the actuating winding 22 of relay 23 is deenergized, thereby leaving the movable switch member 43 in its left-hand position to connect it to the cathode of the tube 13. Thus, the control electrode of the tube 13 is at the same electrical potential as its cathode, thereby making it possible for it to conduct current from the lower brush of armature 3 to the common bus and thus affording a complete circuit for current flow between the output terminals of the transformer 11 through armature 3. Since the field windings associated with both armatures 3 and 5 are always energized by direct current from the positive terminal 15, the armature 3 begins to turn to move the electrodes 1 and 2 toward each other.

The above-mentioned energization of relay 28 has moved the movable switch member 39 thereof into its right-hand position, thereby connecting the control electrode 36 in the double triode 26 to the potential divider 48 to impress a negative voltage on the control electrode 36, thereby preventing current flow through the energizing winding 34 of relay 35 to leave the movable switch members 44 and 47 therein in their right-hand positions, as shown in the drawing. Since the movable switch member 47 of relay 35 is in its right-hand position, current flow through the tube 14 and armature 5 is prevented by the fact that the control electrode of tube 14 is connected to derive bias from the negative bias terminal 24. Similarly, it will be seen that, since the movable switch member 44 of relay 35 and movable member 46 of relay 23 are in their right-hand positions, the control electrode of tube 16 is connected to the negative potential divider 29 thereby preventing any current flow to armature 3 through tube 16.

Now, as soon as the electrodes 1 and 2 are moved into contact with each other, current flow from source A commencing therethrough will move the contact 17 of the "current flowing" relay B together to energize the actuating winding of relay 18. This will cause immediate closure of the contacts 19 and 21. Closure of the contacts 19 will energize the actuating winding

of relay 29 to move the movable switch members 48 and 46 thereof respectively to their right-hand and left-hand positions. Closure of the contacts 21 will impress voltage to begin charging the capacitor 29 negatively and will quickly render the control electrode 25 in the double triode 26 so negative in potential that current flow through the energizing winding 27 of relay 28 will be cut off, causing the movable switch members 39 and 41 to move respectively to their left-hand and right-hand positions as they appear in the drawing. This will be seen to connect the control electrode of tube 13 immediately to the negative terminal of bias source 42, thereby cutting off the current flow through tube 13 and armature 3 so that further movement of the electrode 2 by that armature is stopped. The movement of the switching member 46 to its left-hand position will be seen to disconnect the control electrode of the tube 16 from contact with the negative potential divider 29 and connect it to the bus G to give it the same potential as its cathode. Current flow will, accordingly, begin through armature 3 and tube 16, but since the polarity of tube 16 is opposite to that of tube 13, the direction of rotation of the armature 3 will be the reverse of that previously described, and the electrode 2 will, accordingly, be moved away from the electrode 1, thereby drawing an arc between said electrodes. The above-mentioned deenergization of the relay 28, having caused its switch member 39 to move to the position shown in the drawing, the terminal of capacitor 38 which previously stood connected to a point of negative potential on the potential divider 48 is now disconnected therefrom. The capacitor 38 begins to discharge through the resistor 37 at a rate determined by the resistance thereof, and the potential of control electrode 36 gradually falls to the potential of its cathode 32. Thus, after a predetermined time delay, current flow begins through the control winding 34 of relay 35 to move its switch members 44 and 47 to their left-hand positions. Such movement of the switch member 44 immediately causes the control electrode of tube 16 to derive negative bias from the negative biasing terminal 24 and thereby cuts off current flow through armature 3 and tube 16; but it will be noticed that the resulting cessation of separatory movement of the electrode 2 as a result of such cessation of current flow takes place only after a time delay fixed by the discharge time of capacitor 38 through resistor 37. Thus, it is that the reverse rotation of armature 3 has continued for this same predetermined time, and the length of the arc thereby drawn between electrodes 1 and 2 is similarly fixed by the time constant of the capacitance-resistance circuit 38, 37.

Movement toward the left of the movable switch member 47 of relay 35 will be seen to disconnect the control electrode of tube 14 from the negative bias terminal 24 and to connect it through the movable switch member 46 of relay 23, which is also in its left-hand position to the bus G which has the potential of the cathode of tube 14. Current flow through tube 14 and armature 5 thus is permitted to begin, thus causing said armature to continuously rotate the upper electrode 1, thereby insuring even consumption of the electrode material thereof by the arc.

However, as previously stated, there is considerable unstability in arcs under certain conditions of operation and the current flow through the arc between electrodes 1 and 2 may suddenly cease. When this happens, the relay winding 18

is deenergized by the opening of the contacts 17 of the "current flowing" relay, thereby causing immediate opening of the contacts 19 and 21. This causes immediate movement of the movable switch members 43 and 46 to their respective left-hand and right-hand position in the drawing. The opening of the contacts 21 will disconnect the control electrode 25 from the negative bias source 24, but since the capacitor 29 is negatively charged, it will maintain the negative potential on the control electrode 25 for a considerable time, determined by the adjustment of the resistor 31 through which it discharges. Therefore, current flow through actuating winding 27 of relay 28 remains cut off for a time determined by the time constants of the capacitor resistance 29, 31, and the relay remains in the position shown in the drawing for this predetermined time. Hence the movable switch member 41 continues to connect the control electrode of tube 13 to the negative terminal of bias source 42, thereby preventing current flow through the latter through the armature 3 for the aforesaid predetermined time. During this same predetermined time, the left-hand position of the switch member 39 of relay 28 maintains the control electrode 36 in tube 26 disconnected from the negative potential divider 48 and current continues to flow in actuating winding 34 to maintain the switch members 44 and 47 of relay 35 in their left-hand position. However, the movement of the switch member 46 in the relay 23 consequent upon the deenergization of the latter will be seen to connect the control electrode of the tube 14 to the negative bias terminal 24, thereby cutting off current flow through tube 14 and stopping rotation of armature 5.

As soon as the capacitor 29 has sufficiently discharged, the potential of control electrode 25 in double triode 26 falls low enough to permit current to begin through winding 27 of relay 28, thereby moving the movable switch members 39 and 41 to their respective right-hand and left-hand positions in the drawing. When the switch member 41 moves to its left-hand position, it will be seen that the control electrode of tube 13 is transferred from contact with the negative terminal of bias source 42 to contact through the switch member 43 in relay 23 with the cathode of tube 13. Thereupon, current flow through armature 3 and tube 13 commences, thus moving the electrodes 1 and 2 toward each other to restrike the arc; but it will be noted that this movement has begun only after an interval predetermined by the time constants of the capacitor 29 and the resistor 31.

Movement of the switch member 39 of relay 28 to its right-hand position thereupon connects the control electrode 36 in double triode 26 to the negative bias source through potential divider 48, thereby cutting off current flow through the actuating winding 34 of relay 35, but it will be seen that the resulting movements of the switch members 44 and 47 to their right-hand position merely leaves the control electrodes of tubes 14 and 16 connected to negative voltage points and maintains these tubes in their non-conductive condition.

It will be seen that the entire arc electrode control system has now returned to that condition in which it stood when the motor 3 first began its rotation to move the electrodes 1 and 2 toward contact with each other. A complete cycle of the program of operation of the apparatus has thus taken place and may be repeated

any number of times until power is cut off from the input terminals of transformer 11 to shut down the apparatus.

With this arrangement it will be noted that, if the arc goes out between electrodes 1 and 2 before the armature 3 has fully separated them, the charge on the capacitor 29 will prevent the closure of the contacts of relay 28 for a time sufficient to permit cooling of the electrode from a molten condition which would render their movement into contact with each other disastrous. Furthermore, it will be noted that turning of the electrode 1 by armature 5 takes place only after full separation of the electrodes has been effected and ceases immediately when the arc goes out. These features prevent loss of the electrodes by breakage through freezing together through mechanical movement while they are not sufficiently separated.

It will also be noted that application of voltage to the arc electrodes 1 and 2 is requisite to closure of the contacts 12 which furnish power to the armatures 3 and 5; hence there is no possibility of the armature 3 being energized to move the electrodes 1 and 2 together at a time when no current flow will be present to cause the "current-flowing" relay B to reverse armature 3 and separate the electrodes as soon as they touch. This insures against accidental crushing of the electrodes by improper operation of armature 3.

I claim as my invention:

1. In combination with a pair of electrodes connected to a power source, a motor and means to cause its rotation in one direction to move the electrodes into contact and its rotation in the opposite direction to move said electrodes out of contact, an alternating-current source and a pair of grid-controlled electrical discharge tubes having the cathode of each connected to the anode of the other to control rotation of said motor, means for impressing a negative potential on the control electrodes of both of said tubes while said alternating-current source is deenergized, a first relay means energized to remove said negative potential from one said control electrode when said alternating-current source is energized to thereby cause rotation of said motor in one direction, a second relay means responsive to current flow between said electrodes to deenergize said first relay and reapply the last-mentioned negative potential and to remove the negative potential on the other said control electrode to thereby cause rotation of said motor in the opposite direction, and a time delay to prevent reenergization of said first relay for a predetermined time after cessation of current flow between said electrodes.

2. In combination with a pair of electrodes connected to a power source, a motor and means to cause its rotation in one direction to move the electrodes into contact and its rotation in the opposite direction to move said electrodes out of contact, an alternating-current source and a pair of grid-controlled electrical discharge tubes having the cathode of each connected to the anode of the other to control current flow through said electrodes from said power source, means for rendering one of said tubes conductive upon application of voltage to said electrodes, but for rendering it non-conductive when current flows through said electrodes, means for maintaining a negative potential on the control electrode of the other of said tubes while no current flows from said power source through said electrodes but

for removing for a predetermined time said negative potential in response to current flow through said electrodes, a second motor arranged to impart a turning movement to one of said electrodes; a third grid-controlled electrical discharge tube connecting said second motor to a current source, and means for maintaining said third tube non-conductive until the lapse of said predetermined time and for then rendering said third tube conductive.

3. In combination with a pair of electrodes connected to a power source, a motor and means to cause its rotation in one direction to move the electrodes into contact and its rotation in the opposite direction to move said electrodes out of contact, an alternating-current source and a pair of grid-controlled electrical discharge tubes having the cathode of each connected to the anode of the other to control current flow through said electrodes from said power source, means for rendering one of said tubes conductive upon application of voltage to said electrodes, but for rendering it non-conductive when current flows through said electrodes, means for maintaining a negative potential on the control electrode of the other of said tubes while no current flows from said power source through said electrodes but for removing for a predetermined time said negative potential in response to current flow through said electrodes; a second motor arranged to impart a turning movement to one of said electrodes, a third grid-controlled electrical discharge tube connecting said second motor to a current source, means for maintaining said third tube non-conductive until the lapse of said predetermined time and for then rendering said third tube conductive, and means for maintaining said one of said other tubes non-conductive for a predetermined time after the cessation of current flow between said electrodes.

4. In combination with a pair of electrodes, motor means for moving said electrodes into contact with each other when voltage is impressed on said electrodes but no current flows between them and for then producing a separatory movement between said electrodes in response to current flow between them, means for causing a cessation of movement of said motor means after said separatory movement has continued for a predetermined time, means for then producing another type of movement of one of said electrodes relative to the other said electrode, and means for moving said electrodes again into contact after a predetermined time interval following cessation of said current flow.

5. In combination with a pair of electrodes, motor means for moving said electrodes into contact with each other when voltage is impressed on said electrodes but no current flows between them and for then producing a separatory movement between said electrodes in response to current flow between them, means for causing a cessation of movement of said motor means after said separatory movement has continued for a predetermined time, and means for producing relative rotation of said electrodes only after said separatory movement ceases, and means for moving said electrodes again into contact after a predetermined time interval following cessation of said current flow.

6. In combination with a pair of electrodes connected to a power source, a motor and means to cause its rotation in one direction to move the electrodes into contact and its rotation in the opposite direction to move said electrodes

out of contact, an alternating-current source and a pair of grid-controlled electrical discharge tubes having the cathode of each connected to the anode of the other to control rotation of said motor, a first relay means energized in absence of current flow through said electrodes to render one of said tubes conducting to rotate said motor in one direction, a second relay responsive to current flow through said electrodes to energize the other of said tubes to rotate said motor in the opposite direction upon initiation of current flow through said electrodes and to deenergize said first relay, and a time delay means to prevent reenergization of said first relay for a predetermined time after cessation of current flow between said electrodes.

7. In combination with a pair of electrodes connected to a power source, a motor and means to cause its rotation in one direction to move the electrodes into contact and its rotation in the opposite direction to move said electrodes out of contact, an alternating-current source and a pair of grid-controlled electrical discharge tubes having the cathode of each connected to the anode of the other to control rotation of said motor, means for maintaining a negative potential on the control electrodes of both of said tubes while said alternating-current source is deenergized, a first relay means energized to remove said negative potential from one said control electrode when said alternating-current source is energized to thereby rotate said motor in one direction, a second relay means responsive to deenergize said first relay to reapply the last-mentioned negative potential and to remove the negative potential on the other said control electrode to thereby cause rotation of said motor in the opposite direction in response to current flow between said electrodes.

8. In combination with a pair of electrodes connected to a power source, a motor and means to cause its rotation in one direction to move the electrodes into contact and its rotation in the opposite direction to move said electrodes out of contact, an alternating-current source and a pair of grid-controlled electrical discharge tubes having the cathode of each connected to the anode of the other to control rotation of said motor, a first relay means energized in absence of current flow through said electrodes to render one of said tubes conductive to cause rotation of said motor in one direction, a second relay means energized in response to current flow through said electrodes to deenergize said first relay and to render the other said tube conductive to rotate said motor in the other direction, means for stopping the last-mentioned rotation of said motor after a predetermined time and for energizing a second motor to rotate one of said electrodes, and a time delay to prevent reenergization of said first relay for a predetermined time after cessation of current flow between said electrodes.

9. In combination with a pair of electrodes connected to a power source, a motor and means to cause its rotation in one direction to move the electrodes into contact and its rotation in the opposite direction to move said electrodes out of contact, an alternating-current source and a pair of grid-controlled electrical discharge tubes having the cathode of each connected to the anode of the other to control rotation of said motor, a first relay means which impresses a negative potential on the control electrode of one of said pair of tubes only when said first

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relay is deenergized thereby permitting current to flow in absence of said negative potential to cause rotation of said motor in one direction, a second relay which impresses a negative potential on the control electrode of the other said tubes only when said second relay is deenergized, means for causing energization of said second relay in response to current flow between said electrodes to deenergize said first relay and to remove said negative potential from the control electrode of said second tube to cause rotation of said motor in the other direction, and a third relay which deenergizes said second relay a predetermined time after initiation of current flow between said electrodes.

10. In combination with a pair of electrodes connected to a power source, a motor and means to cause its rotation in one direction to move the electrodes into contact and its rotation in the opposite direction to move said electrodes out of contact, an alternating-current source and a pair of grid-controlled electrical discharge tubes having the cathode of each connected to the anode of the other to control rotation of said motor, a first relay means which impresses a negative potential on the control electrode of one of said pair of tubes only when said first relay is deenergized thereby permitting current to flow in absence of said negative potential to cause rotation of said motor in one direction, a second relay which impresses a negative potential on the control electrode of the other said tubes only when said second relay is deenergized, means for causing energization of said second relay in response to current flow between said

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electrodes to deenergize said first relay and to remove said negative potential from the control electrode of said second tube to cause rotation of said motor in the other direction, a third relay which deenergizes said second relay a predetermined time after initiation of current flow between said electrodes, and a time delay to prevent reenergization of said first relay for a predetermined time after cessation of current flow between said electrodes.

11. In combination with a pair of electrodes, motor means for moving said electrodes into contact with each other when voltage is impressed on said electrodes while no current flows between them and for then producing a separatory movement between said electrodes in response to current flow between them, means for causing a cessation of movement of said motor means after said separatory movement has continued for a predetermined time, and means for moving said electrodes again into contact with each other after a predetermined time interval following cessation of said current flow.

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