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C. W. THOMAS ET AL
SEQUENCE TIMING APPARATUS

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2 Sheets-Sheet 1

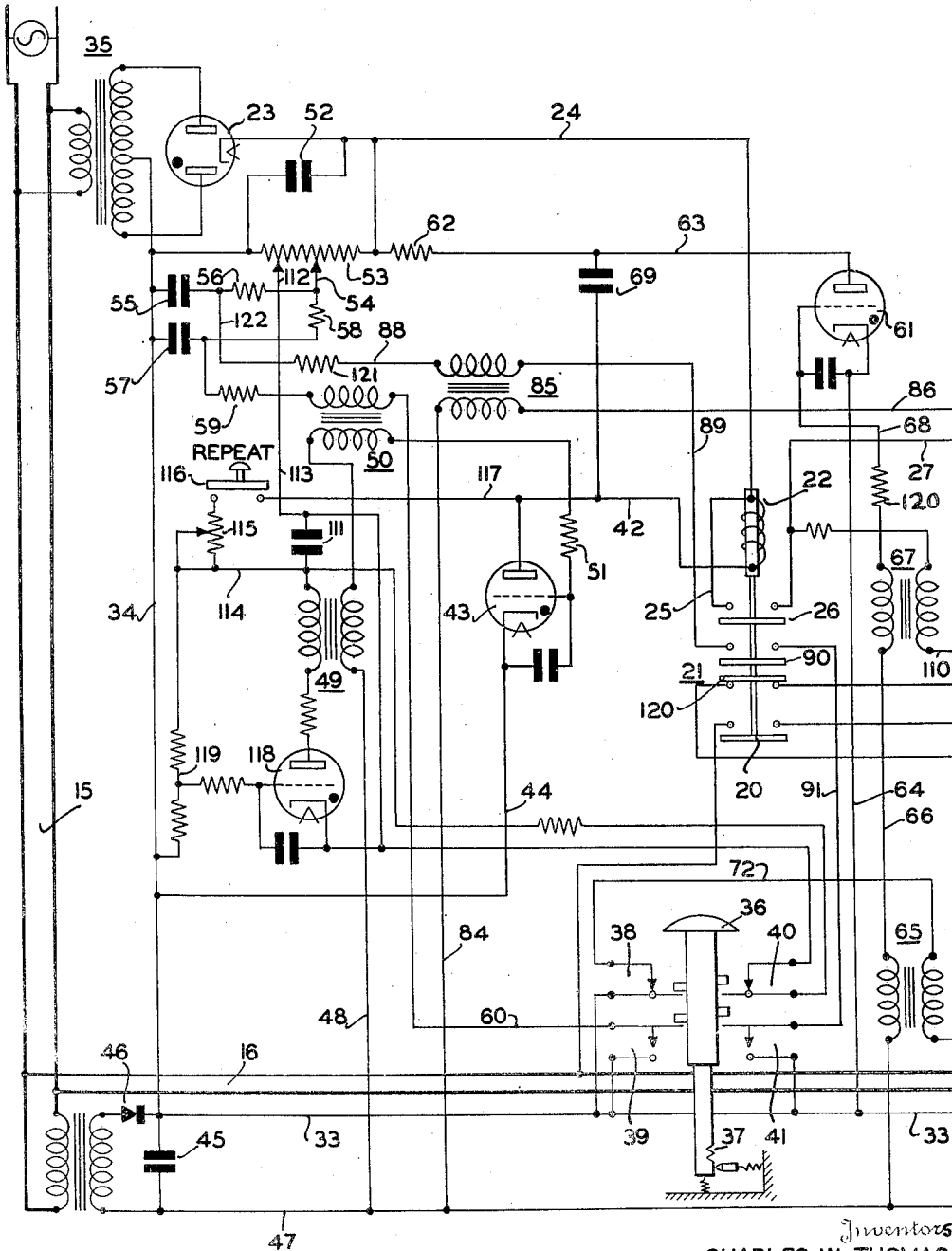


FIG. 1a

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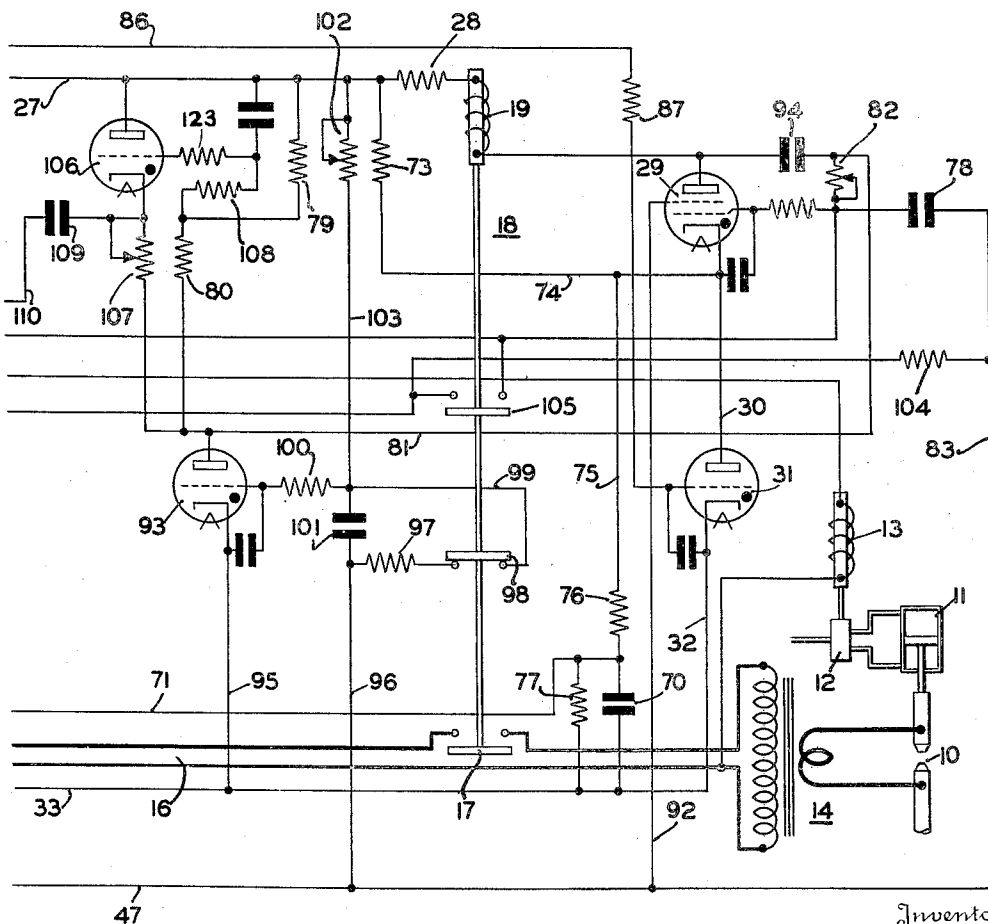


FIG 1b

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SEQUENCE TIMING APPARATUS

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This invention relates to sequence timing apparatus and more particularly to electronic control circuits having utility in the effecting of a plurality of operations in timed sequence, some or all of which operations may be required also to be timed as to duration. Such apparatus is of particular utility, for example, in the controlling of electric resistance spot welding apparatus arranged for automatic recurrent operation in which means is required to first close the electrodes, to provide a "squeeze" time in which the preselected welding force becomes settled, to then initiate and time the duration of welding current flow, to provide a "hold" time during which the plasticized weld nugget may become solidified, to open the electrodes preparatory to the next succeeding cycle of operation, and to thereafter provide an "off" time to allow the machine or operator to relocate work, etc., before the electrodes are again closed to carry out the next succeeding welding cycle.

One of the primary objects of the invention is the provision of a control system of the general character outlined above which is more reliable and consistent in operation than any control system heretofore devised for comparable purposes. A more specific object of the invention in this regard is the provision of an improved circuit and system capable of employing exclusively discharge devices and other circuit components of a rugged and durable nature having readily adjustable and consistent operational characteristics.

Another object of the invention is the provision of an improved control circuit system of the general character specified above which requires a minimum of mechanical relays and switches for its operation whereby the circuit and system as a whole will require less readjustment and maintenance than circuits and systems heretofore proposed for the same purpose. Thus, a principal object of our invention is the provision of a practical commercial apparatus for the purposes indicated which is adaptable to and capable of withstanding the severe conditions of shop service to which welding apparatus is normally subjected.

A further object of the invention is the provision in an electronic sequencing circuit of improved arrangements for effecting the sequential actuation of the respective circuits and of timing the durations of certain or all of such actuations whereby greater reliability and consistency is attained without sacrifice of infinite adjustment. This object is attained, in accordance with one

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embodiment of the invention, by utilizing gaseous discharge devices exclusively, furnished with continuous or direct anode voltages, and by employing certain of the devices in ionization suppressing circuits for certain of the other of the devices.

In resistance welder control circuits it is desirable to provide means to enable the electrodes to be opened substantially immediately upon their closing and without going through the complete cycle of operation to enable the work to be relocated etc. and a still further object of the present invention is to provide for this alternate mode of operation in a simple and dependable manner integrated with the general sequencing aspect of the complete system or circuit. This object is accomplished, in accordance with the preferred embodiment of our invention, by employing a principal gas tube which is made conductive by a readily sensed partial movement of a manual control element and which is operative upon conduction to effect closing of the electrodes and preconditioning, but not activation, of certain of the sequencing circuits. We also provide further means operative automatically upon release of the manual element to deionize this principal tube whereby the electrodes are at once reopened and the system restored to its initial "off" condition.

Other objects of the invention include the simplification of manual control whereby a single manual element may be manipulated to effect only opening and closing of the electrodes, single full cycle operations, or continuing recurrent full cycles of operation, as desired.

These and other objects and advantages of the invention will become apparent upon consideration of the following detailed specification and the accompanying drawing wherein there is disclosed a preferred embodiment of the invention.

The sole figure of the drawing comprised of parts 1a and 1b, on two sheets, is a diagrammatic representation of a sequence control system embodying the principles of our invention. In assembling the drawing parts Figure 1a is to the left of Figure 1b.

The control system illustrated by the drawing is for the purpose of governing the sequence of mechanical movements of the welding electrode 10 of a conventional electric resistance spot welding machine, for example, and is also for the purpose of controlling the duration of welding current flow to these electrodes in properly timed sequence during each succeeding cycle of operation of the welding machine. Electrodes 10 are arranged to be moved toward and away from each other by a cylinder 11 under the control of a

valve 12 which in turn is actuated by a solenoid 13. The arrangement may be such that upon energization of solenoid 13 the electrodes are brought together and welding pressure is applied therethrough while upon deenergization of the solenoid 13 the electrodes are moved apart. Reference numeral 14 designates a welding transformer, the primary of which is arranged to be energized from any suitable alternating current source 15 through a two conductor line 16 having a switching device interposed therein. For purposes of illustration we have utilized, for this switching device, a mechanical contactor 17 forming part of a relay 18 having an actuating solenoid 19 but it should be understood that in actual practice such switching devices will normally take the form of a full-wave ignitron contactor having associated starting tubes, etc., as will be understood.

The energization of solenoid 13 is controlled by a mechanical contactor 20 on a relay 21 having an actuating coil 22 and thus the control cycle desired is effected by the timed sequential energization of the coils 22 and 19. The solenoid 19 is furnished with D. C. energizing current through a circuit traceable from the cathode of a full-wave rectifier 23, conductor 24, conductor 25, contactor 26 of relay 21, conductor 27, resistor 28, coil 19, anode-cathode of a gaseous discharge device 29, conductor 30, anode-cathode of a gaseous discharge device 31, conductor 32, conductor 33, and conductor 34 to the center tap of the secondary winding of a transformer 35, the outer terminals of which winding are connected to the anodes of rectifier 23. Transformer 35 may have its primary winding energized from the source 15 as indicated. Normally during each cycle of operation relay 21 will be pulled in so that coil 19 has its energization controlled by the series connected tubes 29, 31.

We provide a manually operable control device which may conveniently take the form of a foot operated plunger 36 which is normally in upper position but which may be moved into spaced lower positions, notches 37 or other suitable means being provided to indicate to the operator when the first and second position is reached. In the first downward position the plunger 36 opens a switch 38 while closing a switch 39 while in the second or further downward position a switch 40 is opened while a switch 41 is closed. In a manner to be hereinafter explained, the two-stage operation of the control 36 is for the purpose of enabling the welding electrodes to be opened before the flow of welding current during the cycle of operation to correct misplacement of work, etc. As explained above, energization of coil 22 results in closing movement of the welding electrodes and to control the energization of this coil we provide a controlled energizing circuit consisting of the conductor 24, coil 22, conductor 42, anode-cathode of the gas tube 43, and conductor 44 to conductor 34. Tube 43 is normally held nonconducting by a biasing potential developed across capacitor 45 by a rectifier 46 deriving energy from the source 15 and a grid control circuit for the tube 43, which is of the triode type, is traceable from the cathode thereof through conductors 44 and 34, capacitance 45, conductor 47, conductor 48, secondary winding of an impulse transformer 49, secondary winding of an impulse transformer 50, and a current limiting resistor 51 to the control grid of tube 43.

A fairly large smoothing capacitance 52 is connected across the output of rectifier 23 and in

parallel with this capacitance is a voltage divider 53 having an adjustable tap 54 which charges up a capacitance 55 through resistor 56 and a second capacitance 57 through resistance 58. Now it should be observed that capacitance 57 is also in a circuit including a resistor 59, primary of transformer 50, conductor 60, switch 39, and conductors 33 and 34 to the opposite terminal of capacitance 57. Therefore, upon movement of plunger 36 to the first downward position capacitance 57 is discharged through transformer 50 creating an impulse in a secondary winding thereof which is in opposition to the bias furnished by capacitance 45 and sufficient to initiate conduction in tube 43. This tube, being of the gaseous type, remains conductive until snuffed out by conduction in a tube 61 in the manner to be hereinafter described. The anode-cathode of tube 61 is in a circuit which may be traced from conductor 24 through a resistor 62, conductor 63, tube 61, conductor 64, and conductors 33 and 34 to the opposite terminal of the power supply. Tube 61 is normally held nonconducting by the bias furnished by capacitance 45, the grid control circuit being traceable through conductors 64 and 33, capacitance 45, conductor 47, secondary winding of an impulse transformer 65, conductor 66, secondary winding of an impulse transformer 67, resistor 120 and conductor 68 to the control grid of tube 61. The anodes of tubes 43 and 61 are coupled by means of a capacitance 69. During conduction in tube 43 capacitance 69, is charged through resistance 62 by the voltage drop developed in the coil 22 and the terminal of capacitor 69 which is connected to the anode of tube 43 is negative with respect to the terminal which is connected to the anode of the tube 61. Tube 61 may be rendered conducting by momentary energization of transformer 65 and this may be accomplished by releasing plunger 36 to reclose switch 38 to discharge a capacitance 70 through the primary of transformer 65, the circuit being traceable from the lower terminal of switch 38 through conductor 33, capacitor 70, conductor 71, primary of transformer 65, and conductor 72 to switch 38. It should be observed that during the time plunger 36 was depressed and switch 38 was opened the capacitor 70 was charged through a circuit comprising conductors 24 and 25, contactor 26, conductor 27, resistor 73, conductors 74 and 75, resistor 76, and capacitor 70 to conductors 33 and 34. A resistance 77 limits the voltage to which capacitor 70 is charged. The impulse furnished the secondary of transformer 65 is in opposition to the normal bias thus causing tube 61 to conduct and upon initiation of this conduction capacitance 69 momentarily withholds anode potential from tube 43 and tube 43 is extinguished. The effect of this is to deenergize relay 21 to cause the operating head or upper electrode of the welding machine to rise thus recycling the system in preparation for the next complete (or partial) cycle of operation. During conduction in tube 61 capacitor 69 is charged in the opposite direction by the voltage drop across resistance 62 so that upon the next initiation of conduction in tube 43 anode voltage is momentarily withheld from tube 61 to extinguish the latter.

The above described operation provides for the reopening of the electrodes of the machine immediately upon their closing, if desired, without going through the complete cycle of operation. In the normal cycle, however, the control switch operator 36 is moved downward to its second position and upon this occurring the control system

automatically goes through its complete cycle of operation even though the foot treadle is released. The next following timing sequence required to be effected is that of "squeeze time" to allow the mechanical components of the machine to become settled whereby accurate welding pressure is applied before the start of welding current flow. This delay of conduction in tube 29; which tube energizes coil 19 through the circuit-conductors 24 and 25, contactor 26, conductor 27, resistor 28, coil 19, tube 29, conductor 30, tube 31, and conductors 32, 33, and 34; is provided by a timing capacitor 78 which is in discharged condition at the time relay 21 is de-energized but which upon energization of this relay begins to charge at a predetermined rate through a circuit which may be traced from conductors 24 and 25 through contactor 26, conductor 27, resistors 79 and 80, conductor 81, variable resistor 82, capacitor 78, conductors 83 and 47, capacitor 45, and conductor 34 to the opposite terminal of the power supply. In this circuit the potential of capacitance 45 is additive to the potential developed by rectifier 23 so that an increased voltage is available for the charging of time capacitance 78. Of course, tube 31 must first be conducting before tube 29 can conduct and this is provided for by a separate anode circuit for tube 31 which may be traced from conductors 24 and 25, contactor 26, conductor 27, resistor 73, conductors 74 and 30, tube 31, and conductors 32, 33 and 34. Tube 31 is normally held nonconducting by the control grid biasing circuit including the cathode, conductors 32 and 33, capacitor 45, conductors 47 and 84, secondary of impulse transformer 85, conductor 86, and resistor 87 to the control grid of tube 31. Now upon the foot switch 36 being depressed fully downward capacitor 55 (previously charged by tap 54) is discharged through the primary of transformer 85 by means of the circuit-conductor 122, resistor 121, conductor 88, primary of transformer 85, conductor 89, contactor 90 of relay 21, conductor 91, switch 41, and conductors 33 and 34 to the opposite side of capacitor 55.

Tube 29 is provided with a shield grid which is negatively biased by the charge on capacitor 45 through the shield grid lead 92 so that the positive biasing potential furnished the control grid of tube 29 by the charging of the capacitor 78 must be increased by a corresponding value in order to fire the tube 29. This brings the critical voltage up into the straight portion of the charging curve, bearing in mind the added potential available for charging capacitor 78, thereby greatly increasing the accuracy of the timing particularly when line voltage may be fluctuating.

To time the period of energization of relay 18 and consequently the duration of welding current flow we provide a grid-controlled gaseous discharge device 93 the anode of which is coupled with the anode of tube 29 by means of conductor 81 and capacitor 94. Tube 93 is normally held nonconducting by the circuit-conductors 95 and 33, capacitance 45, conductors 47 and 96, resistor 97, contactor 98 on relay 18, conductor 99, and resistor 100 to the control grid of tube 93. Immediately upon the closing of relay 18 and the consequent opening of contactor 98 a timing capacitor 101 in the grid circuit of tube 93 begins to charge through conductor 27, variable resistor 102, conductor 103, and conductors 96 and 47 and upon the potential of the positive side of capacitor 101 reaching a predetermined value the tube 93 begins to conduct (anode voltage being furnished through resistors 79 and 80) and the discharge of

capacitor 94 through tube 93 momentarily interrupts the anode potential for tube 29 thereby extinguishing tube 29. It should be observed that capacitor 78 is discharged through a resistance 104 by closing of a contactor 105 on relay 18. Further, it should also be observed that capacitance 94 is charged during conduction of tube 29 to a value represented by the voltage drop across the coil 19 of relay 18 with the negative side coupled with the anode of tube 29. Thus the adjustment of potentiometer 102 determines the duration of energization of the welding current controlling relay 18.

As explained above it is necessary, in the welding cycle, to maintain welding pressure for a predetermined interval following the cessation of flow of welding current, commonly termed "hold time", and this is provided for in the illustrated system by delaying the deenergization of solenoid 13 (or coil 22 of relay 21) a predetermined interval following initiation of conduction in tube 93. For this purpose, we provide a tube 106 having its anode connected with the conductor 27 and its cathode connected with the anode circuit of tube 93 by means of the variable resistor 107. Tube 106 is normally held nonconducting by a biasing circuit including resistors 107, 80, and 108, and 123, the latter being in the control grid lead of tube 106. To overcome the normal negative bias on tube 106 we provide a timing capacitor 109 which is in the circuit leading from conductor 27 through the primary winding of impulse transformer 67, conductor 110, resistor 107, and tube 93. Thus upon conduction in tube 93 capacitor 109 charges at a rate determined by the setting of potentiometer 107 and in a direction to overcome the bias on tube 106. Following a predetermined interval after initiation of conduction in tube 93 the voltage of capacitor 109 is sufficient to overcome the bias on tube 106 and the latter becomes conducting to discharge capacitor 109 through the primary of transformer 67. The impulse furnished the control grid of tube 61 by transformer 67 causes this tube to conduct thereby extinguishing tube 43 in the manner previously described to restore the entire system to its initial condition preparatory to the next cycle of operation.

The system described above is that employed for manual initiation of each succeeding cycle of operation and the circuit for automatically effecting recurrence of the successive cycles will now be described, it being understood that an appreciable "off time" is required intermediate each successive cycle for the purpose of relocating work, etc.

We therefore provide means for properly timing impulse energization of the primary of transformer 49 (a secondary of which is in the control grid circuit for tube 43) in proper sequence as required. For this purpose we provide a timing capacitor 111 which is arranged to be charged at a variable rate by the adjustable tap 112 of the voltage divider 53 through a circuit including conductor 113, capacitor 111, conductor 114, variable resistor 115, manual switch 116 (which is closed when the system is set for automatic repeat), conductor 117, coil 22, and conductor 24 to the positive side of the D. C. power supply. Capacitor 111 is arranged to be discharged through the primary winding of transformer 49 by a control tube 118 which is arranged to be held normally nonconducting by a voltage dividing resistor network 119 coupled between the positive side of timing capacitor 111

and the negative terminal of the D. C. power supply. Upon capacitor 111 reaching a predetermined charge the potential at the grid tap of network 119 is sufficient to overcome the bias of tube 118 and it conducts to discharge capacitance 111 as aforesaid. This action reinitiates conduction in tube 43 which had previously been extinguished by the firing of tube 61 and a new cycle of operation is thus automatically commenced. The normally closed switch 40 of the foot treadle 36 is provided to hold capacitance 111 in discharged condition when the treadle 36 is in upward position so that there is no automatic recycling when the treadle 36 is released. The system will, however, follow through its instant cycle regardless of when the treadle is released from its second downward position.

Relay 21 is provided with an additional contactor 120 which is normally closed but in parallel with the normally open contactor 105 of the relay 18 so that immediately upon the energization of relay 21 (the closing of the welding electrodes) the timing capacitor 78 can begin to charge up from 0 potential through the timing resistors 79, 80 and 82.

It should now be apparent that we have provided sequence timing apparatus of the electronic circuit type which accomplishes the objects initially set out. By the use of dependable gaseous discharge devices and a minimum number of mechanical relays and contactors the system is made especially adaptable to commercial use on production equipment and is sufficiently rugged and dependable to withstand the severe conditions normally encountered in such service. We consider our present arrangements of firing and extinguishing the control tubes in the respective sequence circuit to be highly advantageous in systems of the general nature involved herein particularly because of the possible wide range of adjustment as to time intervals and durations, because of the dependability of the resulting circuit activations and by deactivations, and because of the perfect adaptability of these arrangements for use in conjunction with a manual control device which is capable of readily effecting different modes or extents of operation of the equipment with which the control system is associated.

The general operation of the system illustrated is such that with the parts in their respective positions indicated and upon the cathodes of the various tubes being properly heated by the filament circuits, not shown, downward movement of plunger 36 fires tube 43 by discharge of capacitance 57 through transformer 50. This results in energization of relay 21 and of solenoid 13 to close the electrode and also in the charging of the interconnected capacitor 69. If the treadle is now released tube 61 is fired extinguishing tube 43 thus recycling the system. If, however, the treadle 36 is pushed full downward tube 31 is fired by discharge of capacitance 55 through transformer 85 so that upon timing capacitor 78 timing out its period tube 29 is fired to energize solenoid 19 of relay 18 which commences the flow of welding current. Interlocking capacitor 94 is then charged and upon the timing capacitor 101 timing out its period tube 93 is fired to extinguish tube 29 thereby opening relay 18. This terminates welding current flow and after a predetermined hold time tube 106 is fired to discharge capacitor 109 through transformer 67 to fire tube 61 which in turn extinguishes tube 43 thereby opening relay 21 to open the electrodes and to

remove the anode voltage from the tubes 31, 93 and 106 thus extinguishing these tubes. If the system is set for automatic repeat by closure of switch 116 timing capacitor 111 acts through tube 118 to again fire tube 43 after a predetermined time lapse to start a new cycle of operation.

From the above, it should be observed that the single control member 36 may be manipulated to effect only opening and closing of the electrodes, single full cycle operations (by moving member 36 to second downward position and then releasing), or automatic repetitions of full cycles (by holding member 36 in fully downward position).

The specifically described and illustrated embodiment of our invention should be considered as illustrative only as obviously many changes may be made therein without departing from the spirit or scope of the invention. Reference should therefore be had to the appended claims in determining the scope of the invention.

We claim:

1. Sequence timing apparatus comprising a pair of gaseous discharge devices each having a control grid and an associated circuit for impressing a D. C. voltage on its anode, a capacitor interconnecting the anodes of said devices, said circuits being operative to charge said capacitor upon conduction in either discharge device, a third gaseous discharge device, control relays in the anode circuits of one of said pair of devices and of the third discharge device, a switch to initiate conduction in the said one of the devices of said pair, and a timing circuit to initiate conduction in said third discharge device upon the expiration of a predetermined time interval following the initiation of conduction in said one of said devices of said pair.

2. Apparatus according to claim 1 further including a timing network to initiate conduction in the other device of said pair upon the expiration of a predetermined time interval following conduction in said third device.

3. Apparatus according to claim 1 further including a manual control member having two operative positions, means responsive to the movement of said member into and out of one of said positions to actuate said switch and to initiate conduction in said other of said devices of said pair, respectively, and means responsive to the movement of said member into the other of said positions to actuate said switch and to render operative said timing means.

4. A sequence timer for an electric resistance welding machine having solenoid operated means for controlling the closing of the welding electrodes and solenoid operated controlling means for controlling the flow of welding current thereto the combination of a controlled gaseous discharge device in the energizing circuit for said first solenoid, a second controlled gaseous discharge device in the energizing circuit for said second solenoid, a suppresser circuit for each of said devices operative upon activation to effect deionization of said devices if conducting, a switch to initiate conduction in said first device, and a timing circuit to initiate conduction in said second device upon the expiration of a predetermined time interval following the initiation of conduction in the first device.

5. A timer according to claim 4 further including a second timing circuit to activate the suppresser circuit for said second device upon the expiration of a predetermined time interval following initiation of conduction in said second

device, and a third timing circuit to activate the suppresser circuit for the first discharge device upon the expiration of a predetermined interval following the extinguishment of the second discharge device.

6. A device according to claim 4 further including a manual operable control member movable into first and second positions in sequence, means associated with said member to actuate said switch upon movement of said member into first position and to activate the suppresser circuit for said first device upon the retraction of said member from said first position, and means operative upon said member reaching its second position to initiate operation of said first mentioned timing circuit.

7. A sequence timer for an electric resistance welding machine having means for moving the welding electrodes and means for controlling the flow of welding current thereto the combination of an energizing circuit for each of said means, a controlled gaseous discharge device in each of said circuits, a suppresser circuit for each of said devices, a manually operable control member having two operating positions, means operable upon said member being moved into and out of one of said positions to initiate conduction in the device in the first of said energizing circuits and to activate the associated suppresser circuit, respectively, and means including timing means operable upon said control member being moved into the other of its positions, to initiate conduction in the device in said first energizing circuit and to thereafter initiate conduction in the other of said devices and to activate the suppresser circuit for the device in said first energizing circuit in timed sequence.

8. A system according to claim 7 further including a timing circuit operable upon said member being held in said second of its positions to automatically reinitiate conduction in the device in the energizing circuit for the first mentioned means upon the expiration of a predetermined time interval following extinguishment of the last mentioned device.

9. Apparatus of the character described comprising in combination an energizing circuit having a controlled gaseous discharge device therein, a second controlled gaseous discharge device, a capacitor interconnecting the anodes of said devices and having associated circuit means whereby the capacitor is charged upon conduction in either of said devices and is operative to momentarily suppress conduction in the conducting device upon initiation of conduction in the nonconducting device, control circuits for each of said devices each having a source of stable reference potential to normally hold the devices nonconducting, a manual control member movable in opposite directions, means to apply to one of said circuits a potential impulse of opposite polarity with respect to said potential upon movement of said member in one direction, and means to furnish a potential impulse of opposite polarity with respect to said reference potential to the other of said control circuits upon movement of said member in the opposite direction.

10. Apparatus according to claim 9 further including timed control means to impress potential impulses onto said control circuits in timed sequence and of a polarity opposite to the polarity of said reference potential.

11. Control apparatus for energizing a pair of relays in timed sequence comprising a source of D. C. current, a first gaseous discharge device connected in series with said source and one of said relays, a second gaseous discharge device connected in series with said source, a capacitor interconnecting the anodes of said first and second discharge devices whereby conduction in one of said first or second discharge devices results in extinguishment of the other of said first or second discharge devices, a manually controlled switch to initiate conduction in said first discharge device, a third gaseous discharge device adapted to be connected in series with said source and the other of said relays, a timing circuit to initiate conduction in said third discharge device a predetermined time after initiation of conduction in said first discharge device, a fourth gaseous discharge device in series with said source, a capacitor interconnecting the anodes of said third and fourth discharge devices whereby connection in one of said third or fourth discharge devices results in extinguishment of the other of said third or fourth discharge devices, a second timing circuit to initiate conduction in said fourth discharge device a predetermined time after initiation of conduction in said third discharge device, and a third timing circuit to initiate conduction in said second discharge device at a predetermined time after initiation of conduction in said fourth discharge device.

12. Apparatus according to claim 11 further including a fourth timing circuit to re-initiate conduction in said first discharge device a predetermined time after initiation of conduction in said second discharge device.

13. Apparatus according to claim 11 further including a manual control member movable from retracted to first and second positions in sequence, said manually controlled switch being actuated by movement of said member from retracted position to first position, a second switch arranged to be actuated by movement of said member from first position to retracted position and being operative to initiate conduction in said second discharge device, and a third switch arranged for actuation by movement of said member to second position for connecting said third discharge device in series with said source and other relay.

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