

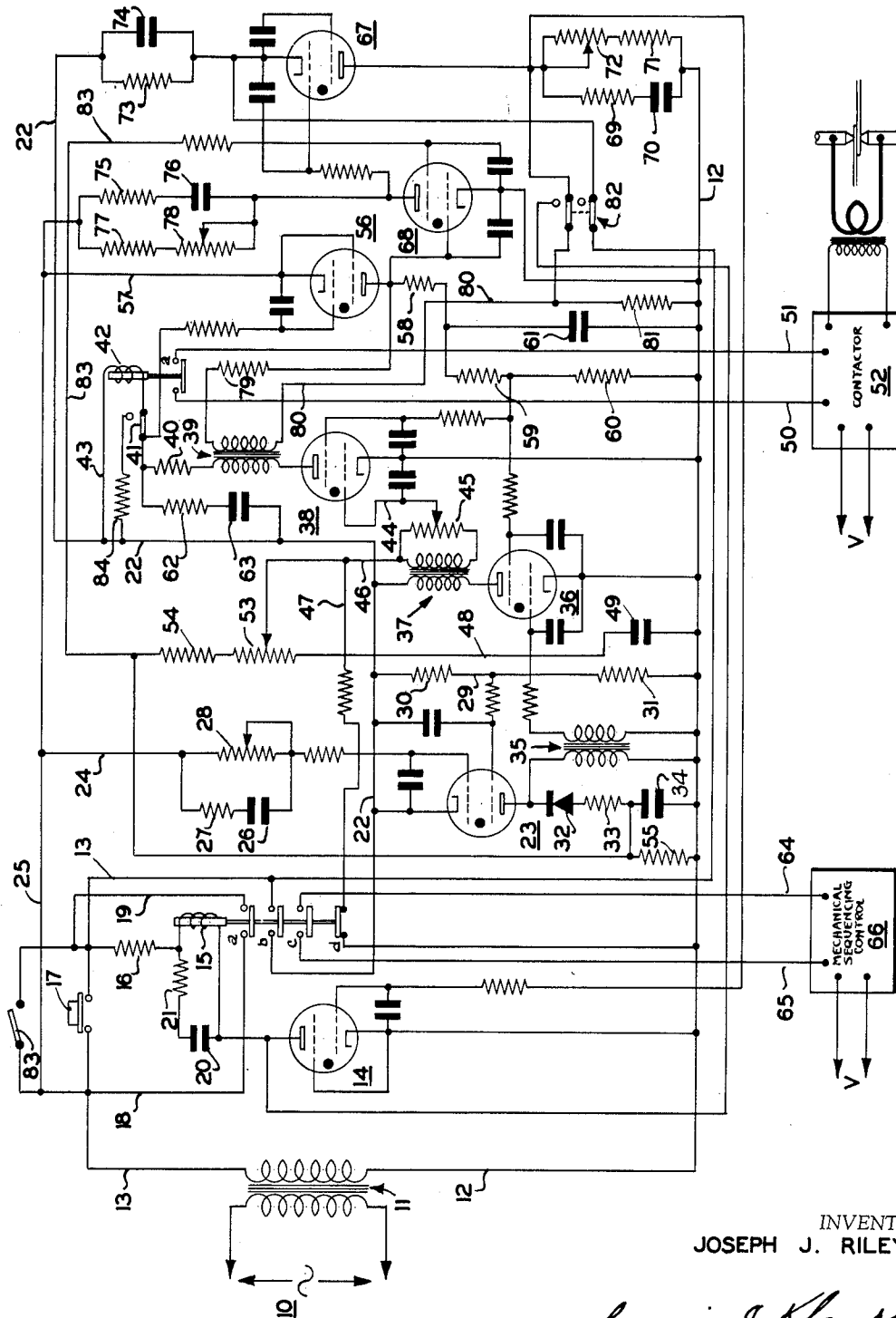
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ELECTRONIC CONTROL CIRCUIT

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ELECTRONIC CONTROL CIRCUIT

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The present invention relates to electronic control circuits and more particularly to a novel electronic timer circuit which finds advantageous application in the electric resistance welding art.

It is an object of the present invention to provide an electronic timing circuit, particularly for use in electric resistance welders, which will retain a high degree of accuracy regardless of wide variations in the applied control voltage. It will of course be understood that in normal electric resistance welding current demands are exceptionally high during the welding operation. Thus unless special facilities are utilized for proper voltage regulation and correction, a substantial drop in the line voltage may be expected. To avoid the deleterious effect of such a voltage drop upon timing accuracy it has heretofore been common practice to provide for voltage regulation in the control circuits. The present invention eliminates the need for these extra components and the additional cost concomitant therewith as will hereinafter appear.

Another object of the present invention is the provision of a timing circuit which is adapted to function entirely from an alternating current source rather than from a direct current source as has been heretofore thought necessary to obtain the high degree of accuracy and control versatility desired in a weld timer.

Another object of the invention is the provision of an electronic timing circuit arrangement having the characteristics enumerated above wherein a single style and size of electronic discharge tube may be used throughout. This arrangement greatly facilitates repair and maintenance of the control as will be understood.

A further and very important object of the present invention is the provision of a novel timing circuit wherein a particular phase of control, as for example initiating, timing and interrupting the flow of weld current in a welding machine, is provided by a single tube, whereby if the tube were to burn out or otherwise cease to function during a control cycle the control phase would automatically be terminated. It is presently common practice, particularly in the resistance welding art, to utilize a conventional "flip-flop" arrangement in timing circuits whereby a control phase is initiated by the firing of one tube or discharge device and is ended by the firing of another which causes the first to be extinguished. It will be apparent that in such an arrangement should the second discharge device fail to fire for any reason, the control phase will continue until the entire apparatus is shut down. Failures such as this, while not common, may cause considerable damage to the apparatus and/or work, and as will hereinafter appear I have substantially precluded the possibility of such an occurrence by my novel circuit.

Other objects and advantages of the invention will become apparent upon full consideration of the following detailed specification and accompanying drawing wherein is illustrated a certain preferred embodiment of my invention.

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The sole figure of the drawing is a schematic representation of a control circuit constructed according to the teachings of my invention and associated with conventional electric resistance welding equipment.

In the drawing, I have shown a conventional alternating current source 10 which connects the primary winding of a transformer 11. Connected across the secondary terminals of the transformer 11, the said terminals being represented by conductors 12 and 13, is a conventional gaseous discharge device 14. In the illustrated embodiment the cathode of discharge device 14 connects the conductor 12 and the anode is connected to one terminal of a relay 15; the other terminal of the relay being connected through a current limiting resistor 16 to the conductor 13. A normally open starting switch 17 is interposed in the conductor 13 whereby discharge device 14 is maintained normally non-conducting, and it will be observed that upon closing of the switch 17 anode-cathode voltage will be applied. The discharge device 14, initially having no hold-off bias, as will presently appear, thus fires on alternate half cycles of applied voltage; the arrangement here being that firing will take place when the conductor 13 is positive with respect to conductor 12. Firing of discharge device 14 energizes the series connected relay 15 and the latter is provided with a conventional holding circuit, comprising conductors 18 and 19 and contacts 15a, connected in shunt relation with the switch 17 whereby the same need be closed but momentarily to initiate a control cycle. To prevent chattering of the relay 15 I have provided a capacitor 20 and resistor 21, connected in parallel with the coil of relay 15, which serve to store energy during the half cycle during which discharge device 14 conducts, and to discharge such stored energy through the relay coil during the non-conducting half cycle.

Closing of the relay 15 connects conductor 22 with conductor 13, through contacts 15b, and thus applies anode-cathode voltage to another gaseous discharge device 23, which as shown is connected at the cathode to conductor 22 and at the anode to conductor 12. The control grid of discharge device 23 is connected with the terminal conductor 13 through conductors 24 and 25, and a tank circuit comprising a capacitor 26 and resistor 27 connected in parallel with a potentiometer 28. Conductor 22, and hence the cathode of discharge device 23, is also connected to the terminal conductor 12 through conductor 29 and series connected resistors 30 and 31. The arrangement is such that when voltage is applied to the transformer 11, but before a cycle has been initiated by closing switch 17, there will be a conduction of current between the cathode and control grid elements of discharge device 23. This action, commonly known as grid rectification, charges the capacitor 26 and accordingly causes the grid of discharge device 23 to become highly negative with respect to the terminal conductor 13. Thus when the relay 15 closes and conductor 22 is connected with conductor 13, discharge device 23 has a high negative control bias and is maintained in a non-conductive state. The charge on the capacitor 26 will, of course, leak off through the tank circuit at a rate determined by the resistance 27 and the setting of the potentiometer 28, and discharge device 23 will thus fire at a predetermined time subsequent to the closing of the relay 15, which predetermined time may be varied within certain design limits by appropriate setting of the potentiometer 28. To insure that discharge device 23 will fire at the proper point in the cycle I have connected the screen grid of the said device to the conductor 29 intermediate resistors 30 and 31. A control signal is thus impressed upon the screen grid which is synchronous with the applied anode-cathode voltage whereby, upon

the discharge device approaching a conductive state through loss of control grid bias the screen grid signal is sufficient to trigger the tube.

Connected in series with the circuit of discharge device 23 are a rectifier 32, resistor 33 and capacitor 34. The primary winding of a transformer 35 is connected in parallel with the three last mentioned elements whereby periodical voltage impulses will be sent to the transformer as discharge device 23 fires on alternate half cycles of the applied potential. The secondary winding of the transformer 35 is connected with the control grid and cathode of another gaseous discharge device 36 whereby the impulses thus sent by discharge device 23 will be applied as positive control grid impulses to discharge device 36. As shown, discharge device 36 is connected to conductors 22 and 12 and thus will fire immediately upon receiving a positive grid impulse from the transformer 35. Note, however, that discharge devices 23 and 36 are reversed in polarity and will fire on opposite half cycles of voltage. The triggering impulse from the transformer 35 is thus an inductive "kick" caused by the cessation of current flow in the primary winding.

Series connected in the anode circuit of discharge device 36 is the primary winding of an impulse transformer 37, the secondary of which connects the control grid of another gaseous discharge device 38. The cathode of discharge device 38 is connected to terminal conductor 12 while the anode is connected through impulse transformer 39, resistor 40, normally closed switch 41, relay 42 and conductor 43 to the conductor 22. Anode-cathode voltage is applied to discharge device 38 upon energization of relay 15 and firing of this tube will thus depend upon subsequent conditioning of its control and/or screen grid. In the present illustration I have provided for a normally zero control grid bias and a relatively high negative screen grid bias which maintains discharge device 38 normally non-conductive. The control grid circuit of the last mentioned discharge device may be traced from the device through conductor 44, potentiometer 45, conductors 46, 47 and 48, capacitor 49 and finally to the terminal conductor 12 where reference is made with the cathode. Connected in parallel with the potentiometer 45 is the secondary winding of impulse transformer 37; the latter being adapted to send a positive signal to the control grid of discharge device 38 whereby the same may be rendered conducting.

It will be observed that relay 42, which is connected in series with discharge device 38, will be energized upon the firing of the device. Normally open contacts 42a of relay 42 thus connect conductors 50 and 51 leading to a welding contactor 52 as indicated. Any of various well known arrangements may be utilized to energize the contactor 52 upon connecting the conductors 50 and 51 as will be understood. The flow of welding current being thus controllable by energizing and de-energizing relay 42, it will be apparent that the weld time may be controlled by timing the duration of conduction of discharge device 38. To accomplish this I provide charging means for the capacitor 49 whereby the same, as it becomes charged, will apply an increasingly negative control grid bias to discharge device 38. Thus it may be understood that the latter may be again rendered non-conducting at such time as the negative bias applied by condenser 49 is of greater magnitude than the positive signal impressed upon the grid by impulse transformer 37.

To properly charge the condenser 49 as explained above I have connected the latter, a potentiometer 53, and resistor 54 in parallel with a resistor 55 and with capacitor 34. The last mentioned capacitor 34, being connected in series with discharge device 23 becomes charged while the same is conducting and it will be apparent that the voltage thus appearing across the capacitor 34 will be applied across the resistor 55 and across the series connected resistor 54, potentiometer 53 and capaci-

tor 49. Capacitor 49 will accordingly charge at a rate determined by the values of resistor 54 and potentiometer 53; the rate being of course variable by adjustment of the potentiometer 53.

For accurate control of discharge device 38 it is desirable, during the firing and timing out thereof, to remove the highly negative screen grid bias which normally operates to aid in keeping the tube in non-conducting state. This I accomplish by providing another gaseous discharge device 56, the cathode of which is connected to terminal conductor 13 through conductors 57 and 25, and the anode of which is connected to the other terminal conductor 12 through resistors 58, 59 and 60. It will be observed that conductor 25 connects conductor 13 between the transformer 11 and starting switch 17 so that anode-cathode voltage is applied to the device 56 upon energization of transformer 11; it not being necessary to first close switch 17. The control grid of discharge device 56 is connected through current limiting resistor 61 to anode circuit of discharge device 38; the connection being made between resistor 40 and switch 41 as shown. Thus upon energization of transformer 11 and prior to the firing of discharge device 38, the control grid of discharge device 56 is either totally disconnected, or is connected to and at the voltage of the cathode; the connection being traceable through deenergized relay 42, conductor 22, contacts 15b, conductor 13, conductor 19, contacts 15a, and conductors 18, 25 and 57. Discharge device 56 thus having no control grid bias prior to the firing of discharge device 38, the former will conduct during this time. The desired screen grid bias for discharge device 38 may then be obtained by connecting the screen to the anode circuit of discharge device 56 between resistors 59 and 60. A capacitor 61 is preferably provided in parallel connection with resistors 59 and 60 in order to at least partially filter the half-wave voltage applied thereto.

It will be understood that the firing of discharge device 38, as initiated by suitable signal from transformer 37, will cause a substantial voltage drop to appear across the terminals of relay 42, and will thus render the control grid of discharge device 56 highly negative with respect to its cathode. Tube 56 thereupon ceases to conduct and the screen grid bias is removed from discharge device 38 as is desired. Resistor 62 and capacitor 63 are conventionally provided in parallel with relay 42 to alternately store and release energy in compensation for the half-wave conduction of discharge device 38. Note also that the screen grid of discharge device 36 is connected in the same manner as that of discharge device 38. The control grid is of course similar.

As discharge device 38 times out and ceases to conduct, the control grid bias is of course removed from discharge device 56 and the latter again begins to conduct. The highly negative screen grid potential is thus restored to discharge devices 38 and 36 to insure that the same do not prematurely re-fire. This is an important feature of the present invention since it substantially eliminates the possibility of accidentally triggering discharge device 38 and thus the weld contactor 52 by unpredictable transients which may appear in the circuit.

The arrangement thus far described provides for a predetermined but variable period of delay between the energization of relay 15 and the firing of discharge device 38 to initiate the flow of weld current. According to the usual practice in the resistance welding art this delay period, commonly known as "squeeze time" is utilized to move the welding electrodes into contact with the work pieces and to apply pressure thereto. For this purpose I utilize normally open contacts 15c to connect conductors 64 and 65 upon energization of relay 15 whereby a desired sequence of mechanical movement of the apparatus may be initiated. Sequencing controls of this nature are well known and are merely schematically indicated here by the reference numeral 66.

It is also usual practice in the art to provide a prede-

terminated delay period, known as "hold time" between the cessation of flow of weld current and retraction of the electrodes from the work. To accomplish this I provide another gaseous discharge device 67 which is operative when conducting to extinguish discharge device 14 and thus deenergize relay 15, causing retraction of the electrodes by virtue of opening contacts 15c. Cooperating with discharge device 67 is yet another gaseous discharge device 68 which operates responsive to the timing out of discharge device 38, and a predetermined time thereafter, to initiate conduction in discharge device 67.

In the instant illustration the anode of discharge device 67 is connected with terminal conductor 12 through a tank circuit comprising a resistor 69 and capacitor 70 connected in parallel with a resistor 71 and potentiometer 72. The cathode of the last mentioned discharge device is connected with conductor 22 through a tank circuit comprising a resistor 73 in parallel with a capacitor 74. The arrangement is such that anode-cathode voltage is applied to discharge device 67 upon energization of relay 15; the device, however, being maintained normally non-conductive through suitable grid control as will appear.

Discharge device 68 has its cathode connected directly to terminal conductor 12 and its anode connected to conductor 25, and hence terminal conductor 13, through a tank circuit comprising resistor 75 and capacitor 76 in parallel with resistor 77 and potentiometer 78. The control grid circuit for this discharge device is traceable from the discharge device through the resistor 79, secondary winding of transformer 39, conductor 80, and resistor 81 to terminal conductor 12. Screen grid control is also provided by connecting the screen between resistors 55 and 54 by means of conductor 83. From inspection of the above described connections it will be observed that anode-cathode voltage will be applied to discharge device 68 upon energization of transformer 11, and the device, having no control- or screen-grid bias prior to the closing of switch 17, will begin conducting immediately. A substantial voltage drop will then appear across the tank circuit comprising elements 75-78, and thus by connecting the grid of discharge device 67 with the anode of discharge device 68 a highly negative control bias will be impressed upon the former, rendering it of course non-conductive, when discharge device 68 is conducting.

Upon the initiation of a welding cycle, and as discharge devices 14, 23, 36 and 38, respectively, begin to conduct, discharge device 68 will be conducting, and accordingly maintaining discharge device 67 in a non-conductive state. As capacitor 34 (anode circuit of discharge device 23) begins to charge, however, an increasingly negative voltage will appear on the screen grid of discharge device 68 which accordingly tends to become non-conductive. Conduction is maintained though, by means of transformer 39 which impresses a positive signal on the control grid. Thus it may be understood that upon the discharge device 38 timing out and the positive grid signals received therefrom through transformer 39 ceasing, discharge device 68 will cease to conduct. Discharge device 67 does not fire immediately, however, since the capacitor 76, having been charged during the conductive period of discharge device 68, maintains a negative bias on the grid of discharge device 67. Dissipation of the charge on capacitor 76 takes place at a rate determined by the values of resistors 75 and 77 and potentiometer 78, and discharge device 67 accordingly becomes conductive after a predetermined delay period.

To terminate the welding cycle upon initiation of conduction in discharge device 67 I have connected the control grid of discharge device 14 to the anode of discharge device 67. Thus the voltage drop appearing across the tank circuit comprising elements 69-72 places a highly negative bias upon the grid of discharge device 14 rendering the same non-conductive and causing relay 15 to be deenergized. Anode-cathode voltage is immedi-

ately removed from discharge devices 23, 36, 38 and 67. Discharge devices 23 and 67 will immediately cease to conduct; discharge devices 36 and 38 having previously ceased to conduct as explained. Deenergization of relay 15 also interrupts current flow in conductors 64 and 65 and it is contemplated that the control 66 will at this time cause the retraction of the electrodes from the work. "Hold time" is thus provided by the delay period between the timing out of discharge device 38 and the subsequent firing of discharge device 67 to deenergize relay 15.

In commercial practice, particularly for mass production operation, it is often desirable to automatically repeat the welding cycle after, of course, a certain delay period or "off time" wherein the work may be moved to properly space the welds. For set-up operations and special work, however, this is not always desirable since the required "off time" may not be subject to accurate prediction. With the illustrated control I may easily provide for both conditions by setting a pair of switches 82 and 83 in either of two operative positions.

Should non-recycling operation be desired, for example, switches 83 and 82 are positioned as illustrated whereby through switch 83 the cathode of discharge device 67 is connected to conductor 13, by-passing resistor 73 and capacitor 74, and the control grid of discharge device 68 is connected with the anode of discharge device 67. Thus the last mentioned device, upon firing, will function as described above to deenergize relay 15. A high negative control grid bias is also placed on discharge device 68 as discharge device 67 fires to prevent premature refiring of the former. To initiate a new cycle of operation it is then of course necessary to reenergize relay 15 by closing the switch 17.

For automatic recycling operation switch 82 is moved to its other position whereby the control grid of discharge device 68 is connected with the anode of discharge device 14. Switch 83, which is connected in parallel with switch 17, is closed to initiate a cycle. The arrangement here is such that when discharge device 67 fires to extinguish discharge device 14 capacitors 70 and 74 are charged. The charging capacitor 74 causes the cathode potential of discharge device 67 to become positive with respect to its control grid and the device accordingly becomes non-conducting. Also, as soon as discharge device 14 ceases to conduct the control grid of discharge device 68, being connected to the anode of the former, becomes highly positive and discharge device 68 begins to conduct instantly. Discharge device 67 is thus prevented from refiring. Discharge device 14 will be held in a non-conducting state by the negative grid potential placed thereon by capacitor 70. The device will of course refire to initiate a new cycle after the charge has dissipated from capacitor 70, and the delay period or "off time" may thus be controlled by appropriate adjustment of potentiometer 72.

For set-up work and other test cycles, wherein it is not desirable to perform an actual weld, I have provided a resistor 84 which connects conductor 22 and a normally open terminal of switch 41. The arrangement is such that switch 41 may be moved to cut relay 42 out of the control circuit and to place the resistor 84, which is preferably of an equivalent load value, into the circuit. Thus it will be understood that the timing components may be operated in the usual manner and under substantially similar conditions for test purposes without energizing relay 42.

It should now be apparent that I have accomplished the objects initially set forth. The timing circuit herein described may be operated entirely from standard alternating current power sources and requires no D. C. supply components. In addition I have substantially eliminated the need for voltage regulating components to compensate for fluctuations in the power source that normally occur during operation of equipment such as

electric resistance welders. By laboratory tests it has been shown that my circuit will operate well within the accuracy standards accepted by the resistance welding art for voltage variations of as much as twenty percent above or below nominal operating voltage. This may be explained by the fact that all timing periods other than the "weld time," i. e., "squeeze time," "hold time" and "off time," are regulated by discharging capacitors. Each of these capacitors must discharge substantially to a zero voltage to end a timing period and it may thus be understood that little variation will result in the discharge time even though relatively wide variations occur in the charge on the capacitor. The "weld time" period, on the other hand, is controlled by a charging capacitor and wide time variations might be expected. It will be noted, however, that transformer 37, which superimposes a positive signal upon the negative biasing potential of charging capacitor 49, is connected, through discharge device 36, across the supply line. Thus the positive impulse received from transformer 37 will vary in magnitude as the supply voltage and will accordingly compensate for variations in the charging rate of capacitor 49, which would of course be affected by the same supply voltage variations.

By eliminating D. C. supply and voltage regulating components from my circuit I not only provide for substantial manufacturing economies but in addition materially simplify maintenance and repair of the circuit. In the arrangement described a single style and size of discharge device is used throughout and the job of replacement is accordingly simplified for plant maintenance crews who understandingly may not be totally familiar with equipment of this nature.

From the foregoing description it should be apparent that in the event of failure of one of the discharge devices to operate, the welding phase of an operating cycle will either not begin, or if begun will time out in the usual manner. This is assured by eliminating the use of an additional discharge device which fires subsequent to the initiation of the welding phase to terminate the same. In the present arrangement capacitor 49, which ends the weld phase, is charged by discharge device 23, and initiation of the weld phase, i. e., firing of discharge device 38, is conditional upon the prior firing of discharge device 23. Thus if the means to end the weld phase does not function, the weld phase will not begin at all. The advantages of this arrangement are manifest.

Another advantageous feature of my invention resides in the use of the relay 15 to open the anode-cathode circuit of discharge device 38 at the end of a cycle of operation. This arrangement positively precludes the possibility of accidental energization of the weld contactor when, for example, work is being moved in the machine preparatory to making additional welds.

With my arrangement for energizing relay 15, and also relay 42, the initial energization will always take place on a voltage cycle of the same polarity since the controlling tubes will pass only alternate half cycles. This is helpful in controlling subsequent timing phases as will be understood.

Having thus specifically described a preferred form of timer circuit incorporating the principles of my invention, what I claim as new and desire to secure by Letters Patent is:

1. In an electronic timing device, a source of alternating current, a timing capacitor and a circuit for charging the same from said source comprising a rectifier, means to initiate operation of said rectifier, a control circuit connected across said source and including a discharge device having an anode, a cathode, and a control grid, means to initiate conduction in said discharge device comprising a second discharge device having an anode and cathode connected across said source and a connection between the anode-cathode circuit of said second discharge device and said control grid, means to

initiate and continue conduction in said second discharge device subject to initiation and continuance of operation of said rectifier, and a circuit connection between a terminal of said timing capacitor and said control grid in bypassing relation to said second discharge device whereby initiation of conduction in said second discharge device initiates conduction in said first mentioned discharge device while conduction in said first mentioned discharge device is interrupted upon the charging of said timing capacitor to a predetermined voltage.

2. Apparatus according to claim 1 further characterized in that said rectifier comprises a third discharge device having an anode, cathode and control grid, said last mentioned anode and cathode being connected across said source, a grid circuit for said third discharge device including an energy storage device and a resistor in parallel, normally open switching means for said source, means to charge said energy storage device while said switch is open whereby upon said switch being closed said energy storage device will maintain said third discharge device in a non-conducting state for a predetermined time.

3. Apparatus according to claim 2 further characterized by said normally open switching means including a fourth discharge device having an anode, cathode and control grid, said anode and cathode being connectable across said source to close said switching means, a grid circuit for said last mentioned discharge device including a fifth discharge device connected across said source, time delay means responsive to cessation of conduction in said first discharge device and operative a predetermined time thereafter to initiate conduction in said fifth discharge device whereby said fourth discharge is rendered non-conducting to open said switching means.

4. Apparatus according to claim 3 further characterized in that said time delay means includes a sixth discharge device having an anode, cathode and control grid, said anode and cathode being connected across said source, a grid circuit for said sixth discharge device associated with said first discharge device whereby said sixth discharge device is rendered non-conducting upon and for a predetermined time after cessation of conduction in said first discharge device, timing means including an energy storing device and a resistor in parallel connected in series with said sixth discharge device adapted to be charged thereby, said fifth discharge device having a control grid, and a grid circuit for said fifth discharge device associated with said last mentioned timing means, the arrangement being such that said fifth discharge device is rendered conducting a predetermined time after said sixth discharge device is rendered non-conducting.

5. In an electronic timing circuit the combination of a power supply; a first discharge device having an anode, cathode and control grid, said anode and cathode connecting the terminals of said power supply; a grid control circuit for said discharge device including the secondary winding of a transformer and a capacitor; a second discharge device connected across said power supply, said second discharge device having an anode-cathode circuit including the primary winding of said transformer, the arrangement being such that said second discharge device when conducting will cause positive potential signals to be impressed upon the grid of said first discharge device; means for charging said capacitor at a predetermined rate whereby an increasingly negative biasing potential is impressed upon the grid of said first discharge device, the arrangement being such that said negative biasing potential exceeds said positive signal after a predetermined charging time whereby said first discharge device is rendered non-conducting; and means associated with said second discharge device and said means to charge whereby conduction of said second discharge device is conditioned upon prior functioning of said means to charge.

6. Apparatus according to claim 1 further characterized in that said circuit for charging includes a third discharge device adapted to apply a charging potential to said

capacitor and a potentiometer associated with said discharge device and said capacitor adapted to regulate the magnitude of said charging potential, and means responsive to the initiation of conduction in said third discharge device adapted to render said second discharge device conductive.

7. In a timer circuit the combination of a power supply; a discharge device having an anode, cathode and control grid, said anode and cathode being connected across said power supply; a grid control circuit for said discharge tube including a positive potential signal generator and a capacitor; means for charging said capacitor at a predetermined rate whereby an increasingly negative biasing potential is impressed upon the grid of said discharge device, the arrangement being such that said negative biasing potential exceeds said positive signal after a predetermined charging time whereby said discharge device is rendered non-conducting; and means associated with said positive potential signal generator and said means to charge whereby functioning of said signal generator is conditioned upon prior functioning of said means to charge.

8. Apparatus according to claim 7 further characterized by said discharge device having a screen grid; and further including a second discharge device having an anode, cathode and control grid, said anode and cathode being connected across said power supply, a grid control circuit for said second discharge device associated with said first discharge device responsive to a non-conductive state of said first discharge device to render said second discharge device conducting and responsive to a conductive state of said first discharge device to render said second discharge device non-conducting; and a screen grid circuit for said first discharge device associated with said second discharge device whereby conduction in said second discharge device causes a highly negative biasing potential to be applied to said screen grid.

9. In a control circuit for electric resistance welding apparatus the combination of a power supply; a first discharge device having an anode, cathode and control grid, said anode and cathode being connected across said power supply; switching means associated with said first discharge device adapted to be energized thereby, said switching means being adapted to control the flow of welding cur-

rent in said apparatus; a grid control circuit for said first discharge device including a positive potential signal generator and a capacitor; means for charging said capacitor at a predetermined rate whereby an increasingly negative biasing potential is impressed upon the grid of said first discharge device, the arrangement being such that upon said biasing potential becoming sufficiently high the positive signal from said generator will be overcome and said first discharge device will be rendered non-conductive, each said signal generator and said charging means including a discharge device, and means rendering conduction of said discharge device for said signal generator responsive to and conditioned upon prior conduction of said discharge device for said charging means.

10. In a control circuit for electric resistance welding apparatus of the type having electrodes movable into and out of welding position; the combination of a power supply, switching means for said power supply, said switching means being adapted upon closing to initiate movement of said electrodes into welding position, a normally non-conductive discharge device connected to said power supply through said switching means, said discharge device being adapted to control the flow of weld current in said apparatus, first control means for said discharge device operative when actuated to cause conduction in said discharge device, second control means for said discharge device a predetermined time subsequent to the actuation thereof to overcome the effect of said first control means to render said device non-conducting, time delay means operative a predetermined time after closing of said switching means to actuate said second control means, and means associated with said first and second control means whereby actuation of said first control means is responsive to and conditioned upon prior actuation of said second control means.

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