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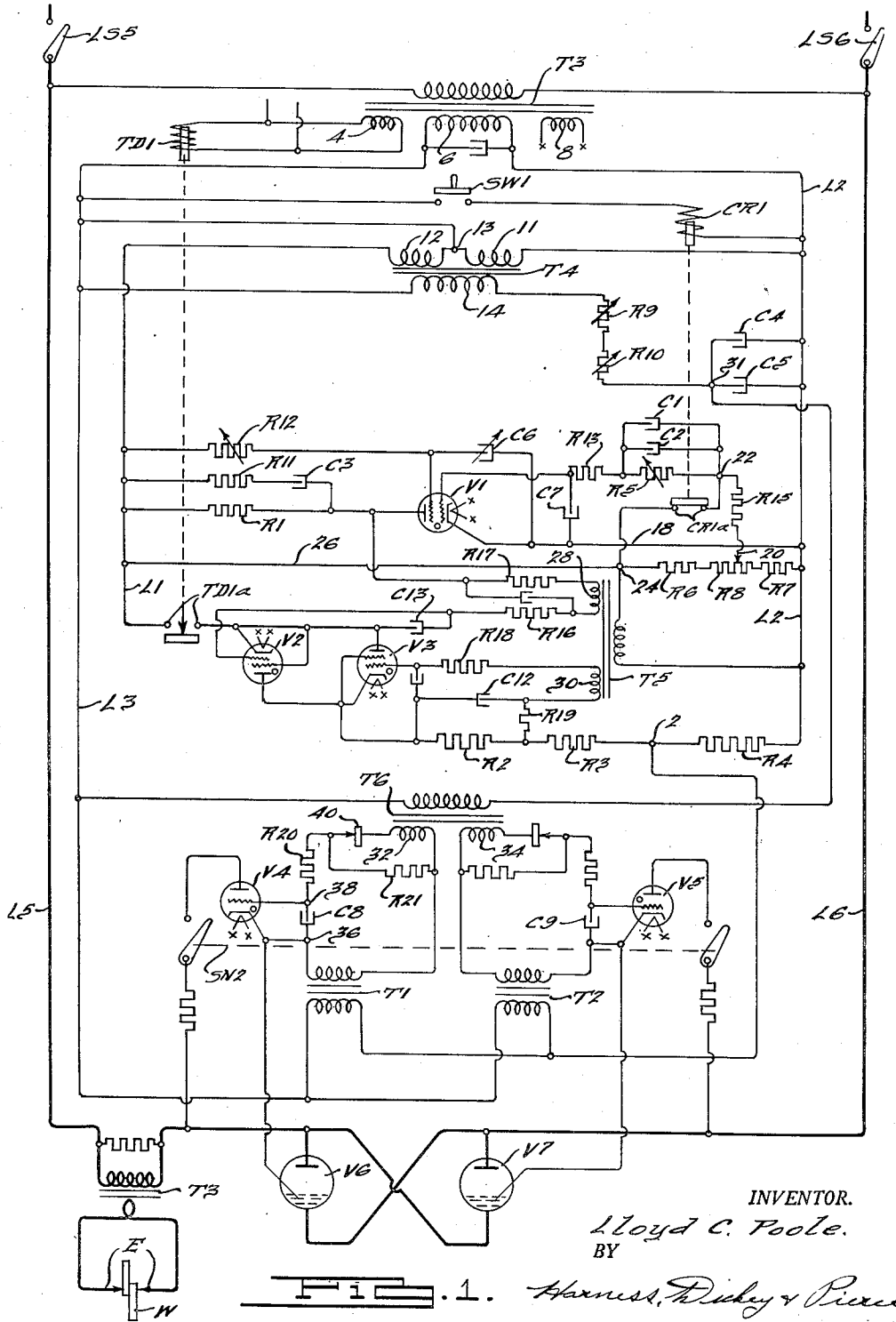
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ELECTRONIC CONTROL APPARATUS

Filed Dec. 29, 1949

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

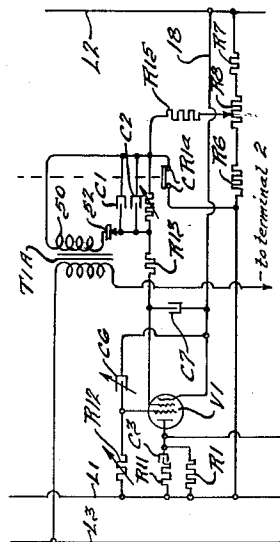
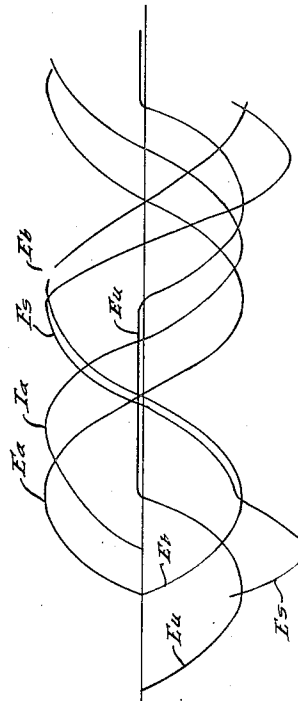
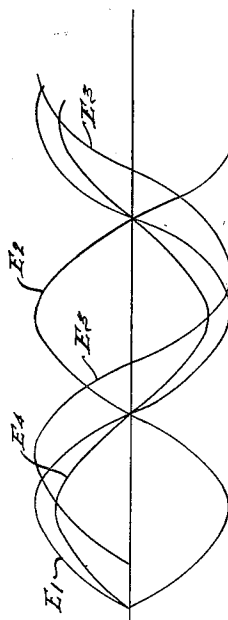
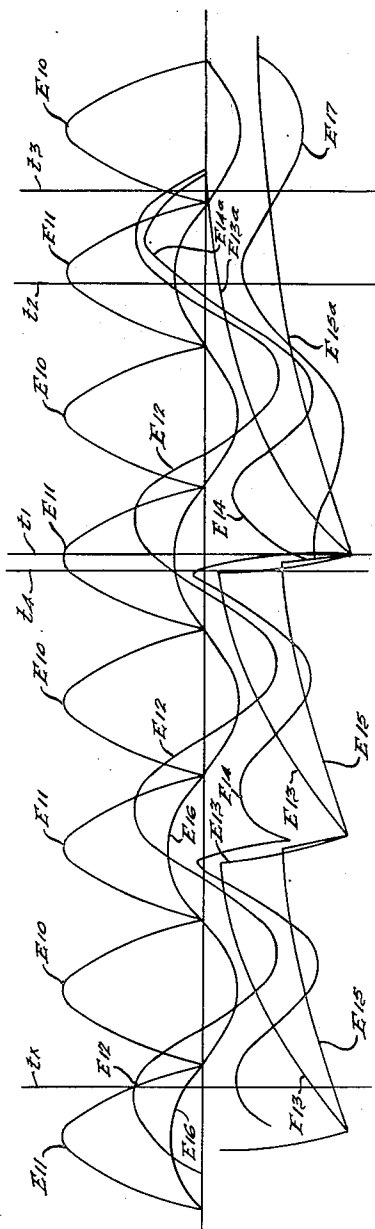


FIG. 6.

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ELECTRONIC CONTROL APPARATUS

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24 Claims. (Cl. 315—252)

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This invention relates generally to electrical timing systems and is particularly adapted among other uses as a timing system for welding apparatus.

An object of this invention is to provide an improved timer of the character described.

Another object of this invention is to provide such a timing means which uses a minimum number of electric valves.

Another object of this invention is to provide such a timing means which is easily and economically manufactured.

A further object is to provide a novel system for controlling a pair of reversely arranged valves.

A further object is to provide in such a system means to insure that one of the valves will always become conductive at a fixed portion of an alternating current voltage wave.

A further object is to provide in such a system such valves in leading and trailing relation.

A still further object is to provide a control for an electric valve which normally maintains such valve nonconductive but controllable to render such valve conductive.

A still further object is to provide such a control which is actuated by a pair of reversely arranged valves.

Another object is to provide a new timing control system for an electric valve.

Other objects of this invention will be apparent from the specification, the appended claims and the drawings in which:

Figure 1 illustrates schematically a timing apparatus embodying the invention;

Figs. 2, 3 and 4 illustrate diagrammatically certain control relations for the controlled valves; and,

Fig. 5 is a modified form of a charging circuit for a timing condenser used in the apparatus of Fig. 1.

Generically the invention comprises an apparatus for energizing an electrical circuit for a predetermined timed interval and in predetermined relation with respect to an alternating potential in response to closure of an initiation switch.

Referring to the drawings, an alternating current potential, from a suitable source, is supplied to the lines L5 and L6 through the line switches LS5 and LS6 respectively. A transformer T3 having a plurality of secondary windings 4, 6 and 8 has its primary winding directly connected across the lines L5 and L6. The winding 4 is

connected across a time delay relay TD1 having normally open contacts TD1a which close a predetermined timed interval subsequent to the energization of transformer T3. The winding 6 is connected between the lines L2 and L3 and supplies a control potential for controlling the time of firing ignitrons V6 and V7. A transformer T4 has its primary winding 11 connected between the lines L2 and L3 and has a pair of secondary windings 12 and 14. One terminal of each of the windings 12 and 14 is connected to the line L3. The other terminal of the winding 12 is connected to line L1 while the other terminal of winding 14 is connected through variable resistors R9 and R10 and capacitors C4 and C5 to the line L2. This arrangement establishes a potential between the lines L1 and L2 which is greater than the potential between the lines L2 and L3. Preferably the windings 11 and 12 have equal numbers of turns whereby the potential between lines L1 and L2 is twice that of the potential between lines L3 and L2.

The anode of the valve V1 is connected to the line L1 through the capacitor C3 and a current limiting resistor R11, as well as being connected to the line L1 through the discharge resistor R1. The shield grid of the valve V1 is connected to the line L1 through a current limiting resistor R12 and to the cathode of the valve V1 through a capacitor C6. The cathode of the valve V1 is directly connected to the line L2 by means of conductor 18. The control grid of the valve V1 is connected to the cathode of the valve V1 through a capacitor C7 and through series-arranged resistors R13, R5 and R15 to the movable tap 20 of the potentiometer resistor R8. Capacitors C1 and C2 are arranged in parallel with each other and in parallel with the resistor R5. The common terminal 22 between the resistors R5 and R15 is connected through the normally closed contacts CR1a of relay CR1 to terminal 24 which is maintained at the potential of line L1 by its connection thereto through the conductor 26. The terminal 24 is connected through the primary winding of transformer T5 to the line L2, thereby placing this primary winding in parallel with the series connected resistors R6 and R7 and potentiometer resistor R8.

The valves V2 and V3 are connected in anti-parallel relation whereby the cathode of valve V2 is directly connected with the anode of valve V3 and the anode of valve V3 is connected to the cathode of valve V2. The cathode of valve V2 is connected through the time delay relay contacts TD1a to the line L1 while the cathode of

the valve V3 is connected through series connected resistors R2, R3 and R4 to the line L2. The control grid of the valve V2 is connected through a resistor R16 to one terminal of one of the secondary windings 28 of the transformer T5. The other terminal of this winding 28 is connected through resistor R17 to the common connection between the capacitor C3 and the anode of the valve V1. Since the cathode of valve V2 is connected to the line L1, it will be apparent that the potential appearing across the capacitor C3 and resistor R11 will appear as a control potential between the control grid and cathode of the valve V2.

The control grid of the valve V3 is connected through resistor R18 to one terminal of a second secondary winding 30 of the transformer T5; the other terminal of which is connected through resistors R19 and R2 to the cathode of the valve V3 whereby the secondary winding 30 is operable to apply a control potential between the control grid and cathode of the valve V3. A capacitor C12 is arranged in parallel relation with the series connected resistors R19 and R2 to provide a phase shift for the valve V3 control potential which will lag the voltage applied across the anode and cathode of the valve V2. This voltage across C12 due to the conduction of valve V2 will be a polarity to render valve V3 conductive and is of sufficient magnitude relative to the blocking voltage applied by winding 30 to render valve V3 conductive so that when the valve V2 has conducted during one half cycle of applied voltage the valve V3 will be rendered conductive during the following half cycle of opposite polarity of said voltage.

The windings 14 and 11 are preferably of an equal number of turns and arranged in polarity to provide in effect a single center tapped winding having the free end of the winding 11 connected through capacitors C4 and C5, terminal 31 and resistors R9 and R10 to the free end of the winding 14. As the relative values of resistance and capacitance of this just described circuit are varied, the phase relation of the voltage appearing between terminal 31 and line L3 will vary with respect to that of the voltage between the free terminals of the windings 11 and 14. Since the phase of the voltage appearing between the lines L5 and L6 bears a definite relation to that of the last mentioned voltage, this phase shiftable voltage appearing between the line L3 and terminal 31 is utilized to supply a control voltage for the valves V4 and V5 which in the present instance is used to render these valves conductive. A transformer T6 therefore has its primary winding connected between the line L3 and the terminal 31 and is provided with a pair of secondary windings 32 and 34 which respectively apply a blocking bias potential between the control grid and cathode of the valves V4 and V5 respectively. One terminal of the secondary winding 32 is connected through the secondary winding of the transformer T1 to terminal 36 which terminal 36 is directly connected to the cathode of the valve V4. The other terminal of the winding 32 is connected to terminal 38 and the control grid of the valve V4 through the resistor R20 and rectifier 40. A resistor R21 is connected across the winding 32 and rectifier 40 to provide for current flow through the rectifier 40 whereby it is effective to prevent the winding 32 from providing any substantial positive grid to cathode potential. A stabilizing con-

denser C8 is connected between the terminals 36 and 38.

The valves V4 and V5 are normally provided with a hold-off voltage from the transformers T1 and T2 respectively. The secondary winding of the transformer T1 is connected between terminal 36 and the common terminal of the resistor R21 and winding 32 whereby it is effective to provide an alternating current bias voltage across the capacitor C8 and consequently the grid and cathode of valve V4. The voltage for energizing the transformers T1 and T2 is derived between the common terminal 2 of resistors R3 and R4 and the common terminal 13 between the windings 11 and 12 as represented by the line L3. Normally there is a difference in potential between the terminals 2 and 13 with the valves V2 and V3 nonconductive. However upon conduction of the valves V2 and V3 this potential difference disappears since the resistance of the resistors R4 and the sum of the resistance of resistors R2 and R3 plus the effective resistance of the valves V2 and V3 is matched with the voltage across the windings 11 and 12 respectively.

It is believed that the remainder of the construction can best be understood by a description of the operation which is as follows:

The circuits are prepared for operation by closure of the line switches LS5 and LS6 whereby the lines L5 and L6 are supplied with an alternating potential. This closure energizes the transformer T3 whereby winding 4 supplies a potential for energizing the time delay relay TD1 which will close its contacts TD1a at a predetermined subsequent time. Winding 6 energizes the lines L2 and L3 whereby the winding 11 of transformer T4 is energized as well as transformer T3. Winding 8 energizes the filaments of valves V1-V5 inclusive through suitable control circuits which may include transformers if desired to maintain the filament to cathode voltage within permissible values.

Energization of winding 11 causes transformer T4 to provide a voltage between lines L1 and L2 which is greater than that between lines L3 and L2. If, as is preferred, the windings 11 and 12 are similar the voltage between lines L1 and L2 will be twice that between lines L3 and L2. Since transformers T1 and T2 are connected between terminals 2 and 13 and valves V2 and V3 are normally nonconductive or blocked these transformers will be energized to place an alternating voltage between the grids and cathodes of the valves V4 and V5 which voltage is phased with respect to the voltage applied to these main electrodes so that a blocking grid-to-cathode bias will be applied during the time that their anodes are positive with respect to their cathodes as is diagrammatically shown in Fig. 4.

Since the relationships are the same for each set of valves V4, V6 and V5, V7 except that they are 180° out of phase with respect to each other, Fig. 4 will explain the voltage relationships of each set of valves and a detailed explanation will be given only as to one set. Ea represents the potential supplied between the anode and cathode of the valve V6 which during periods of nonconduction of valves V6 and V7 will be that appearing across the anodes and cathodes of the valve V4. Ia represents the normal load current which will flow through valves V6 and V7 during their conduction and is shown in lagging relation to the voltage Ea since this is the normal relation for the welding application shown. Eb represents the blocking bias voltage applied

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by the transformer T1 which acts to maintain the valve V4 blocked. Eu represents the unblocking bias voltage furnished by transformer T6 to the valve V4 which as shown comprises a negative half sine wave with the positive half substantially cut off due to the effect of the rectifier 49. Es represents the sum of the voltages Eb and Eu. The voltage Eu may be phase shifted with respect to Ea and Eb by the resistors R9 and R10 to provide a control voltage Es which may be set to provide for conduction of the valve V4 at the desired point on the voltage wave Ea to provide so called "heat control."

Energization of lines L1 and L2 also energizes the transformer T5 whereby windings 28 and 30 are energized. Winding 28 is phased to place a firing voltage between the grid and cathode of the valve V2 but is initially prevented from doing so by the now open contacts TD1a. Winding 30 places a blocking bias between the grid and cathode of the valve V3.

Capacitor C3 will be charged by conduction of the normally conductive valve V1 from line L1 through current limiting resistor R11, capacitor C3, anode to cathode of valve V1, and conductor 13 to line L1 which soon reaches a fully charged condition. Relay CR1 is normally de-energized whereby its normally closed contacts CR1a act to complete a charging circuit for the capacitors C1 and C2. This circuit extends from line L1 through conductor 26, contacts CR1a, capacitors C1 and C2, resistor R13, grid to cathode of valve V1 to line L2.

As soon as the relay TD1 times out, it closes its contacts TD1a whereby the winding 28 is effective to supply its potential between the grid and cathode of valve V2 in series with the potential of the now charged capacitor C3. The values and polarities of these potentials are such that the valve V2 is held blocked.

It is to be assumed that the electrodes have now been clamped against the work by suitable means, not shown, so that they are in condition to be energized to perfect a weld. Upon closure of the initiation switch SW1, the relay CR1 will be energized through an obvious circuit opening its contacts CR1a de-energizing the charging circuits for the condensers C1 and C2 and placing the charge thereacross between the grid and cathode of the valve V1 to negatively bias this grid with respect to the cathode whereby the valve V1 is rendered nonconductive permitting the charge on the capacitor C3 to bleed off through the discharge resistor R1 which after a predetermined timing allows valve V2 to conduct. Conduction of valve V2 causes valve V3 to conduct in trailing relation with respect to the valve V2 for completing a circuit between the lines L1 and L2. The values of resistors R2, R3 and R4 are so chosen that with the valves V2 and V3 conducting the terminal 2 intermediate the resistors R3 and R4 will be rendered at an intermediate potential which is the same potential as line L3 whereby the transformers T1 and T2 which normally act to maintain the valves V4 and V5 blocked will be de-energized, permitting these valves V4 and V5 to conduct. Conduction of the valves V4 and V5 causes the ignitrons V6 and V7 respectively to conduct whereby current flows between lines L5 and L6 to energize the welding transformer T3 causing current to flow between the electrodes E through the work W. When the charge on the condensers C1 and C2 has discharged through the resistor R5 to a predetermined value, the differential

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voltage set up through the resistor R7 and potentiometer resistor R8 will again permit the valve V1 to conduct thereby again charging the capacitor C3 to block the valves V2 and V3. The rendering of the valves V2 and V3 nonconductive again establishes potential difference between the terminal 2 and line L3 which re-energizes the transformers T1 and T2 for blocking the valves V4 and V5 thereby terminating current flow through the valves V6 and V7.

In Fig. 3, E1 illustrates the voltage relationship of anode to cathode of the valve V2, E2 the voltage of anode to cathode of V3, E3 the unblocking voltage established across capacitor C12 due to the conduction of V2, and E4 is the blocking voltage of the winding 30 applied to valve V3. The voltage E3 is seen to lag the voltage E1 due to the lagging effect of circuit elements consisting of capacitor C12 and R19 so that when the proper anode to cathode voltage appears across the valve V3 the sum of the voltages E3 and E4 will produce a resultant voltage to fire or render valve V3 conductive at substantially the beginning of the voltage pulse, E2.

In Fig. 2, there is shown diagrammatically the voltage relations acting to control the conduction of valve V2 with respect to valve V1 so that irrespective of the time in the voltage cycle which is applied between the anode and cathode of valve V2 that the switch SW1 is closed, the valve V2 will always commence its conduction in predetermined relationship to the voltage applied to valve V2 and in predetermined relation with the timing out of the weld time condensers C1 and C2.

E10 represents the positive half cycles of the anode to cathode voltage on the valve V2; the negative portions having been omitted for clarity. E11 represents the positive half cycles of the anode to cathode voltage on the valve V1 and its phase relation with respect to E10; the negative portions having been omitted for clarity. E12 represents the voltage component applied between the grid and cathode of the valve V2 by the winding 28 which due to the phase shift imparted thereto by the capacitor C13, will lag the voltage E11 and will therefore tend to permit firing of the valve V2 only during the first part of the positive cycle of the voltage E10. E13 represents the potential across the capacitor C3 and resistor R11 due to the charging action of the valve V1 and discharging action of resistor R1 during the positive and negative half cycles of voltage E11 respectively. E14 represents the sum of the voltages E12 and E13 or the actual bias voltage applied between the grid and cathode of the valve V2. Curve E15 represents the voltage component applied between the grid and cathode of the valve V1 by the capacitors C1 and C2. Curve E16 represents the alternating current voltage component applied between the grid and cathode of the valve V1 due to the voltage drop across the righthand portion of the potentiometer R8 and the resistor R7. Curve E17 represents the sum of the voltages E15 and E16.

The valve V1 is of the type generally sold to the trade under the designation 2050 in which the shield grid controls not only the conduction between the anode and cathode of the valve but also the conduction between the grid and cathode of the valve. Condenser C6 and resistor R12 are chosen to phase the voltage applied between the shield grid and cathode of the valve V1 with respect to a voltage applied between the anode and cathode of the valve V1 so that the

valve V1 is rendered in a conductive condition for conducting either anode to cathode or grid to cathode closely adjacent the 90° point on the voltage wave applied between the anode and cathode thereof. For reasons to be pointed out hereinafter it may be desirable in many instances to render the capacitor C6 and resistor R2 variable whereby the time in the voltage wave E11 at which the valve V1 conducts may be controlled. Such an arrangement controls the charging of the capacitors C1, C2 and C3 whereby they may be brought once each cycle of the voltage E11 to a fully charged condition. Termination of conduction by the valve V1 initiates simultaneously the discharge of the capacitors C1, C2 and C3.

The line *tx* represents a time subsequent to closure of the line switches LS5 and LS6 and to the closing of contacts TD1a and in which equilibrium conditions of operation have been established. If now the switch SW1 is closed during the time interval from *t1* to *t2* the valve V1 will fail to fire during the next positive wave of voltage E11 and the condenser C3 will discharge along the curve E13a providing a grid to cathode voltage on valve V2 represented by the curve E14a. The valve V2 will then be fired at time *t3*. If the switch SW1 is closed during the interval between *t4* and *t1*, the valve V1 having commenced conducting will continue to conduct and recharge the condenser C3 but due to opening of the contacts CR1a the charging circuit for the condensers C1 and C2 will be opened and their charge would be the charge at the instant the contacts CR1a opened. As indicated above, by phasing the bias voltage between shield grid and cathode of the valve V1 so that valve V1 is rendered conductive just before the 90° peak of the voltage E11 is reached. The time interval in which the switch contacts CR1a may open to terminate charging of the condensers C1 and C2 and yet permit condenser C3 to charge is so small that an opening of the contacts CR1a during this period is extremely improbable. Under the extreme condition, in which contacts CR1a are opened at the exact instant valve V1 conducted, the introduced error would not be more than one cycle of time of the alternating current wave E10 which is well within usual commercial tolerances for most welding.

If it is desired to insure against such a possibility, the modified form of charging circuit shown in Fig. 5 may be used wherein the charging circuit for the timing condensers C1 and C2 may include a second secondary winding on one of the transformers T1 or T2 or a separate transformer T1A connected in parallel with the transformers T1 and T2. One terminal of the secondary winding 50 of transformer T1A is connected through a rectifier 52 to one terminal of the capacitors C1 and C2 while its other terminal is connected to the other terminals of these capacitors. The winding 50 is phased with respect to the voltage between lines L3 and L2 such that a charging voltage of the polarity indicated will be applied to the condensers C1 and C2 when line L3 is positive with respect to line L2. In this manner the capacitors will be recharged each cycle of the voltage applied between lines L3 and L2 in which the valves V2 and V3 are not conductive. As indicated in Fig. 2 there will always be a constant number of positive half cycles of the voltage E11 between the time valve V1 is rendered nonconductive and valve V2 is rendered conductive. As shown the capacitor C3 and re-

sistors R1 and R11 provide for one such half cycle. Furthermore the combined effect of capacitor C3 and winding 28 always provides for the valve V2 to be rendered conductive at a fixed point in the voltage wave E10 so that the discharging of the capacitors C1 and C2 will always remove the blocking bias voltage on valve V1 at a fixed time interval subsequent to firing of the valve V2 for terminating the weld interval. This effect is independent of the place along the voltage waves at which the switch SW1 is actuated.

Subsequent to a predetermined time the condensers C1 and C2 will have discharged sufficiently so that the voltage E17 will become sufficiently positive, or less negative, so that the valve V1 will again be rendered conductive. Conduction of the valve V1 will again establish a charge on the condenser C3 which will apply a blocking potential between the grid and cathode of valve V2 whereby it is rendered in a condition to re-establish conduction if it is already nonconductive or if valve V2 is already conducting such charge on the capacitor will prevent its conduction during the next cycle in which its anode is positive with respect to its cathode. The valve V3 which conducts each subsequent half cycle to the half cycle in which valve V2 conducts will cease conducting after the next half cycle in which valve V2 conducts. At this point it is to be noted that the superimposing of the alternating potential E16 on the potential E15 acts to provide a more definite time for the conduction of valve V1.

When valves V2 and V3 cease conducting the potential of terminal 2 again becomes different from line L3 and the transformers T1 and T2 are again energized to impress a blocking voltage on the valves V4 and V5 respectively which overcomes the conducting voltage set up by transformer T5 whereby valves V4 and V5 are rendered ineffective to fire the valves V6 and V7 to terminate the flow of welding current.

If the switch SW1 has been opened during this time the condensers C1 and C2 will become charged as stated above and the system is in condition for a subsequent operation. If the switch SW1 is kept closed, the condensers C1 and C2 cannot charge because of the open contacts CR1a and the system will remain in condition to prevent conduction of the valves V6 and V7. The electrodes can now be unclamped from the work.

As shown and described, the switch SW1 is manually operated but it is to be distinctly understood that the switch SW1 and/or circuit to the relay CR1 may be controlled by a suitable sequencing circuit which acts to automatically clamp the electrodes to the work and to close the switch SW1 subsequently to the clamping of the electrodes on the work and which will, at the termination of the weld period, open the switch SW1 and unclamp the electrodes. If desired the sequencing circuit may include means for delaying the unclamping of the electrodes for a predetermined time interval subsequent to the termination of the flow of welding current and may also include means for insuring against reclosure of switch SW1 and reclamping of the electrodes within a desired time interval.

What is claimed and is desired to be secured by United States Letters Patent is as follows:

1. In a timing apparatus of the character described for controlling the flow of electrical energy from a source to a load, a first valve having main electrodes and a control electrode, a

second valve having main electrodes and a control electrode, said main electrodes of said valves being arranged in opposite polarity between a pair of conductors adapted to be energized from a source of alternating potential, an energy storage device connected intermediate one of said first valve main electrodes and one of said source conductors, circuit means connecting said device between one of said second valve main electrodes and said second valve control electrode, a second storage device, and means including switch means for selectively connecting said second device between said first valve control electrode and said one conductor and between said first valve control electrode and the other of said first valve main electrodes.

2. In a timing apparatus of the character described for controlling the flow of electrical energy from a source to a load, a first valve having main electrodes and a control electrode, a second valve having main electrodes and a control electrode, said main electrodes of said valves being arranged in opposite polarity between a pair of conductors adapted to be energized from a source of alternating potential, an energy storage device connected intermediate one of said first valve main electrodes and one of said source conductors, circuit means connecting said device between one of said second valve main electrodes and said second valve control electrode, a second storage device, means including switch means for selectively connecting said second device between said first valve control electrode and said one conductor and between said first valve control electrode and effectively to the other of said first valve main electrodes, and means supplying an alternating potential between said second valve control electrode and said second valve one main electrode.

3. In a timing apparatus, a first transformer having a pair of windings, a first pair of conductors adapted to be energized from a source of alternating electrical potential and connected across a first of said windings, means connecting said pair of windings in voltage additive series connection, a second pair of conductors energized by the voltage derived from said series connected windings, a first electric valve having an anode and a cathode and a control electrode, an energy storage device, a first circuit means serially connecting said device and said anode and said cathode between said second pair of conductors with said device intermediate said anode and one of said second pair of conductors, a pair of valves each having an anode and a cathode and a control electrode, a first conductor means connecting said anodes and said cathodes of said pair of valves in anti-parallel relation, one of said pair of valves having its said cathode connected to said one conductor, a second conductor means connecting said control electrode of said one valve to said first circuit means intermediate said first valve anode and said storage device, a second circuit means including a pair of serially connected resistor elements connecting the said cathode of the other of said pair of valves to the other of said second pair of conductors, a second transformer having a pair of windings, a third circuit means connecting one of said second transformer windings between a common connection of said serially connected elements and a common connection between said first transformer windings.

4. In an apparatus of the character described, an electric valve having an anode and a cathode

and a control electrode, a first supply means operable to supply an alternating potential, a second supply means operable to supply an alternating potential, a rectifier, circuit means serially connecting said first and said second means and said rectifier, means connecting said circuit means between said control electrode and said cathode, a resistor connected in shunt with one of said supply means and said rectifier and means for controlling the relative phases of the potentials supplied between said control electrode and said cathode by said first and second means.

5. In a timing apparatus, a first transformer having a pair of windings, a first pair of conductors adapted to be energized from a source of alternating electrical potential and connected across a first of said windings, means connecting said pair of windings in voltage additive series connection, a second pair of conductors energized by the voltage derived from said series connected windings, a first electric valve having an anode and a cathode and a control electrode, an energy storage device, a first circuit means serially connecting said device and said anode and said cathode between said second pair of conductors with said device intermediate said anode and one of said second pair of conductors, a pair of valves each having an anode and a cathode and a control electrode, a first conductor means connecting said anodes and said cathodes of said pair of valves in anti-parallel relation, one of said pair of valves having its said cathode connected to said one conductor, a second conductor means connecting said control electrode to said first circuit means intermediate said first valve anode and said storage device, a second circuit means including a pair of serially connected resistor elements connecting the said cathode of the other of said pair of valves to the other of said second pair of conductors, a second transformer having a pair of windings, a third circuit means connecting one of said second transformer windings between a common connection of said serially connected resistor elements and a common connection between said first transformer windings, a third winding for said first transformer, means connecting said first transformer first winding and said third winding in series additive relation to provide a pair of end terminals and a center terminal, a load circuit comprising a resistive and a reactive impedance element serially connected together and connected between said end terminals, a third transformer having a first and second winding, means connecting said third transformer first winding between said load circuit and said center terminal, a second electric valve having an anode and a cathode and a control electrode, circuit means for serially connecting together the other of said pair of windings of said second transformer and said third transformer second winding, said last-named circuit means being connected between said second valve control electrode and cathode.

6. The combination of claim 5 in which a rectifier is serially connected between said third transformer second winding and said third valve control electrode and in which an impedance element is connected to said rectifier on the side thereof adjacent said third valve control electrode and to the common connection between said third transformer second winding and said second transformer other winding.

7. In a timing apparatus, a first transformer having a pair of windings, a first pair of conduc-

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tors adapted to be energized from a source of alternating electrical potential and connected across a first of said windings, means connecting said pair of windings in voltage additive series connection, a second pair of conductors energized by the voltage derived from said series connected windings, a first electric valve having an anode and a cathode and a control electrode, an energy storage device, a first circuit means serially connecting said device and said anode and said cathode between said second pair of conductors with said device intermediate said anode and one of said second pair of conductors, a pair of valves each having an anode and a cathode and a control electrode, a first conductor means connecting said anodes and said cathodes of said pair of valves in anti-parallel relation, one of said pair of valves having its said cathode connected to said one conductor, a second conductor means connecting said control electrode to said first circuit means intermediate said first valve anode and said storage device, a second circuit means including a pair of serially connected resistor elements connecting the said cathode of the other of said pair of valves to the other of said second pair of conductors, a second transformer having a pair of windings, a third circuit means connecting one of said second transformer windings between a common connection of said serially connected elements and a common connection between said first transformer windings, a capacitor connected in parallel circuit with a portion of one of said resistor elements, a third transformer having an output winding connected between said control electrode of the other of said pair of valves and serially through said last-named capacitor and said resistor element portion to said other valve cathode.

8. In a timing apparatus, three conductors adapted to be supplied with an alternating potential in which the potential between a first of said conductors and a second of said conductors is equal to the potential between said first conductor and a second of said conductors and the potential between said second and said third conductors is the sum of said first and said second named potential, switch means, impedance means having end connections and an intermediate connection, circuit means connecting said switch means and said impedance means in series circuit between said second and said third conductors, and a controlling circuit connected between said intermediate connection and said first conductor.

9. The combination of claim 8 in which said impedance means comprises two portions which have the same ratio as the potential between said first and second conductors and said second and third conductors whereby when energized through said switch means said impedance means acts to establish a potential at said intermediate connection which is equal to the potential of said first conductor whereby to effectively de-energize said controlling circuit.

10. The combination of claim 8 in which said switch means comprises a pair of anti-parallel connected electric valves.

11. The combination of claim 10 in which one of said valves comprises a main electrode and a control electrode, in which means is provided to establish a control potential between said control electrode and said main electrode, and in which switch means is provided for controlling said potential.

12. The combination of claim 11 in which said

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establishing means comprises an energy storage device and said last-named switch connects said device between two of said conductors.

13. In a timing apparatus, three conductors operable to be energized from an alternating current source in a manner to provide voltages between a first of said conductors and each of the other of said conductors and to provide a voltage between said other two conductors which is greater than the voltage between said first conductor and either of said other conductors, a pair of electric valves connected in anti-parallel relation, each of said valves being controllable by a bias potential placed between a control electrode and a main electrode, a plurality of impedance elements, means connecting said main electrode of one of said valves to one of said other conductors, means connecting said impedance elements in series circuit between a second of said other conductors and said main electrode of another of said pair of valves, a controlling impedance element and a third electric valve arranged in series circuit between a pair of said conductors, circuit means for placing the potential appearing across said controlling impedance element between said main electrode and said control electrode of a first of said pair of valves, and means controlling conduction of said third valve.

14. The combination of claim 13 in which a control circuit is connected between said first conductor and to said series connected elements at a point intermediate a pair of said series connected elements.

15. The combination of claim 14 in which means is provided to establish a bias potential between said main electrode and said control electrode of a second of said pair of valves tending to hold said second valve nonconductive, and means actuated as a consequence of current flow through said first valve for overcoming said last-named bias potential whereby said second valve will be rendered conductive as a consequence of the conduction of said first valve.

16. The combination of claim 15 in which said last-named means comprises a reactive impedance element connected in parallel relation with one of said series connected impedance elements and in series circuit with said bias potential establishing means.

17. In a timing apparatus, a pair of conductors adapted to be energized from a source of electrical energy, a first impedance element, a first electric valve having main electrodes and a control electrode, circuit means connecting said element to one of said pair of conductors and to one of said main electrodes and connecting the other of said main electrodes to the other of said pairs of conductors, a second impedance element, means connecting said second element to said control electrode, means selectively connecting said second element to receive a potential from either of said conductors, a second electric valve having main electrodes and a control electrode, a third impedance means, circuit means connecting one of said second valve main electrodes to said one conductor and connecting the other of said second valve main electrodes through said third impedance means to said other conductor, conductor means connecting said second valve control electrode to a portion of said first-named circuit means intermediate said first valve one main electrode and said first impedance element.

18. The combination of claim 17 in which said third impedance means is provided with an in-

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intermediate top connection, in which is provided a third conductor adapted to be energized from such source at a potential intermediate the potential between said pair of conductors, and in which a control circuit is energized by the potential appearing between said intermediate connection and said third conductor.

19. The combination of claim 18 in which said first and second impedance elements are energy storage devices and said third impedance means is resistive in character.

20. The combination of claim 19 in which an alternating potential supplying means is provided in said last-named conductor means.

21. In a timing apparatus of the character described for controlling the flow of electrical energy from a source to a load, a first valve having main electrodes and a control electrode, a second valve having main electrodes and a control electrode, said main electrodes of said valves being arranged in opposite polarity between a pair of conductors adapted to be energized from a source of alternating potential, an energy storage device connected intermediate one of said first valve main electrodes and one of said source conductors, means providing a controlled rate of discharge for said storage device, circuit means connecting said device between one of said second valve main electrodes and said second valve control electrode, a second storage device, means providing a controlled rate of discharge for said second storage device, and means including switch means for selectively connecting said second device between said first valve control electrode and said one conductor and between said first valve main electrodes.

22. In a timing apparatus of the character described for controlling the flow of electrical energy from a source to a load, a first valve having main electrodes and a control electrode, a second valve having main electrodes and a control electrode, said main electrodes of said valves being arranged in opposite polarity between a pair of conductors adapted to be energized from a source of alternating potential, an energy storage de-

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vice connected intermediate one of said first valve main electrodes and one of said source conductors, circuit means connecting said device between one of said second valve main electrodes and said second valve control electrode, a second storage device, means including switch means for selectively connecting said second device between said first valve control electrode and said one conductor and between said first valve control electrode and the other of said first valve main electrodes, and means connected in series with said first-named energy storage device and said second valve control electrode for supplying an alternating potential between said second valve control electrode and said second valve one main electrode.

23. A network for connection between a control electrode and a cathode of an electric valve, a pair of terminals adapted to be connected across such electrode and cathode, a first source of alternating potential adapted to provide an alternating potential bias between said pair of terminals, a second source of alternating potential, and means energized from said second source for applying instantaneous potentials from said second source between said pair of terminals proportional to the instantaneous potential of said second source during corresponding half cycles thereof and to prevent said second source from supplying a potential proportional to the instantaneous potential of said second source during opposite corresponding half cycles thereof.

24. The combination of claim 23 in which means is provided to phase shift the voltage potential applied by said second source.

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