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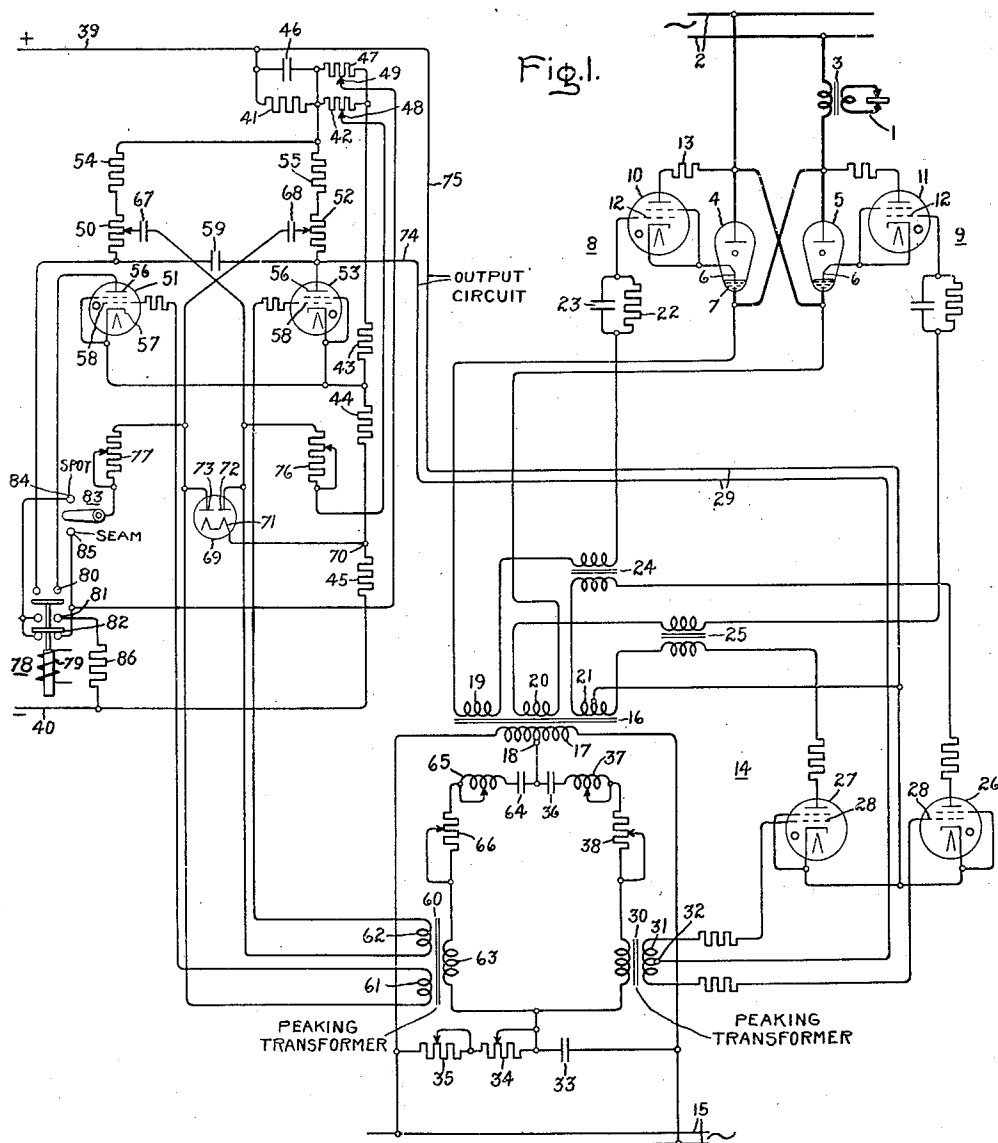
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2,370,178

ELECTRIC VALVE CIRCUIT

Filed June 29, 1942

• 2 Sheets-Sheet 1

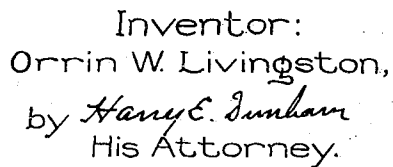


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2 Sheets-Sheet 2



UNITED STATES PATENT OFFICE

2,370,178

ELECTRIC VALVE CIRCUIT

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18 Claims. (Cl. 250—27)

My invention relates to electric valve translating circuits and control circuits therefor, and more particularly to electric valve circuits for producing a control voltage such as a single impulse of control voltage or a series of impulses of control voltage.

In many industrial applications, it is frequently desirable to control electrical apparatus or mechanical devices to obtain operation for a predetermined interval of time, or to obtain operation periodically or intermittently during accurately determinable intervals of time. For example, in electric valve resistance welding systems it is frequently desirable to effect energization of the welding circuit for a predetermined interval of time, or to effect recurrent or intermittent energization of the welding circuit and to control not only the period of energization or the duration of each period of energization, but also to control the interval of time between successive energizations. In accordance with the teachings of my invention described hereinafter, I provide a new and improved electric valve control circuit wherein greater precision is obtained than that afforded by the prior art arrangements, and which employs apparatus of simple construction and arrangement and which is not prohibitive with respect to the cost of manufacture.

It is an object of my invention to provide a new and improved electric control circuit.

It is another object of my invention to provide a new and improved electric valve timing or control circuit.

It is a further object of my invention to provide a new and improved electric valve timing means of the parallel-inverter type wherein a single impulse of control voltage or a series of impulses of control voltage are produced.

It is a still further object of my invention to provide new and improved electric valve translating apparatus wherein the conductivity of electric valve means employed in the translating apparatus is accurately controlled by means of a timing voltage of rectangular or square wave form which is precisely synchronized with respect to the voltage of an associated alternating current supply circuit.

Briefly stated, in the illustrated embodiment of my invention I provide new and improved electric valve translating apparatus and an electric valve control or timing circuit therefor. The timing circuit is of the parallel-inverter type which is energized from a source of direct current and includes a pair of parallel-connected electric circuits each including an electric discharge device of the type employing an ionizable medium, such

as a gas or a vapor, and in which the duration and the time of occurrence of the impulses of control voltage are accurately determinable relative to the voltage of an associated alternating current circuit. Means are provided for assuring a minimum value of negative unidirectional biasing potential, the value of which is established or chosen with respect to the peaked control voltage, which renders the electric discharge devices conducting, and the control characteristic of the electric discharge devices so that the discharge devices are always rendered conducting at the desired times, thereby reducing to a minimum any deviations in operation of the timing circuit which would be involved by variations in the voltage of peaked wave form or by undesirable variations in the constants of the impedance elements used in the timing circuit.

For a better understanding of my invention, reference may be had to the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims. Fig. 1 of the accompanying drawings diagrammatically illustrates an embodiment of my invention as applied to an electric valve translating system, and Fig. 2 represents certain operating characteristics of the timing circuit and the associated electric valve translating apparatus.

Referring now to Fig. 1 of the accompanying drawings, I have there illustrated my invention as applied to an electric valve translating system for energizing a load circuit, such as a welding circuit 1, from an alternating current supply circuit 2 through electric translating apparatus including a transformer 3 and electric valve means 4 and 5 which may be inversely connected to supply alternating current to energize transformer 3 and the welding circuit 1. The electric valve means 4 and 5 may be of the type employing an ionizable medium, such as a gas or a vapor capable of supporting an arc discharge, and each may comprise an immersion-igniter control member 6, associated with a cathode 7, and which initiates an arc discharge upon the transmission thereto of a current of predetermined minimum value.

The immersion-igniter control members 6 may be energized by excitation circuits 8 and 9 which include control electric valve means 10 and 11. These electric valve means may also be of the type employing an ionizable medium, and each may comprise a control grid 12 the potential of which determines the times at which current conduction is initiated. If desired, the excitation circuits 8 and 9 may be of the type responsive to

the magnitude and polarity of the voltage applied between the anodes and cathodes of electric valve means 4 and 5. For example, the control electric valve means 10 and 11 may be connected between the anodes and the immersion-igniter control member 7 through current limiting resistance 13.

The times at which the control electric valve means 10 and 11 are rendered conducting, and the periods of conduction of these electric valve means and the main electric valve means 4 and 5 may be controlled by a control circuit 14 which may be of the type disclosed and claimed in a co-pending patent application Serial No. 449,021 of Maurice E. Bivens, filed concurrently herewith and assigned to the assignee of the present application. Although my invention is illustrated as applied to a system including a particular control circuit for the electric valve means 10 and 11, it will be appreciated that the control and timing circuit described hereinafter is not limited thereto and may be applied with equal facility to other arrangements. The control circuit 14 may be energized from an alternating current circuit 15, or may be energized from the supply circuit 2. Control electric valve means 10 and 11 are normally maintained non-conducting by impressing on the control grids 12 thereof biasing voltages, such as alternating voltages, displaced substantially 180 electrical degrees with respect to the voltages impressed across the anodes and cathodes thereof. These biasing voltages may be furnished by windings of a transformer 16 energized from circuit 15. Transformer 16 includes a primary winding 17 having an electrically intermediate terminal 18 and may include secondary windings 19, 20 and 21. Windings 19 and 20 are connected to control electric valve means 10 and 11, respectively, and impress on the grids 12 thereof hold-off or biasing alternating voltages. If desired, additional biasing means for producing negative unidirectional biasing potentials may also be employed. For example, I may employ parallel connected resistances 22 and capacitances 23 connected in series relation with windings 19 and 20. The control electric valve means 10 and 11 are rendered conducting at desired times by the superposition on the above described biasing potentials of impulses of voltage sufficient to overcome the effect of the biasing potentials. This control may be effected by employing transformers 24 and 25 connected in series relation with windings 19 and 20, respectively, and which are energized at the desired times from secondary winding 21 of transformer 16 through electric valve means 26 and 27, respectively. The electric valve means 26 and 27 may also be of the type employing an ionizable medium and each comprises a control grid 28. The anode-cathode circuits of electric valve means 26 and 27 are connected to winding 21 through transformers 24 and 25, respectively.

Electric valve means 26 and 27 are controlled, that is, selectively rendered conducting and non-conducting, by means of a control or output circuit 29, the potential of which is controlled by the timing means described hereinafter. Normally, the circuit 29 impresses a negative unidirectional biasing potential of predetermined magnitude on the grids 28 of electric valve means 26 and 27 to maintain these electric valve means nonconducting, and the potential of circuit 29 may be varied to raise the voltage impressed on grids 28 for a single predetermined interval of time, or to raise the potential of the grids intermittently. The voltage of circuit 29 is superim-

posed on a control voltage which may be an intermittent or periodic voltage of peaked wave form produced by a saturable inductive device or transformer 30 having a secondary winding 31 provided with an intermediate connection 32 which is connected to one terminal of control circuit 29. The other terminal of control circuit 29 is connected to the cathodes of electric valve means 26 and 27.

Peaking transformer 30 may be energized from circuit 15 through a bridge-type circuit, one branch of which comprises secondary winding 17 of transformer 16, and the other branch of which comprises a phase shifting means such as a capacitance 33 and a variable impedance element such as variable resistances 34 and 35. Suitable filtering means, such as a capacitance 36, an inductance 37 and a resistance 38, may be connected in series relation with the primary winding of peaking transformer 30. Resistance 38 may be adjustable in order to control the magnitude of the voltage induced in secondary winding 31, and inductance 37 may be adjustable to control the phase of the voltage induced in winding 31. Adjustment of resistances 34 and 35 also controls the phase of the voltage impressed on grids 28 of electric valve means 26 and 27 and, hence, controls the time at which the electric valve means 10, 11, 4 and 5 are rendered conducting, thereby controlling the magnitude of the current transmitted to the welding circuit 1. The control voltage provided by circuit 29 controls the interval of energization of the welding circuit 1, and where intermittent energization is employed also controls the time of each energization and the period of time between successive energizations.

Referring now more particularly to the apparatus which energizes the control circuit 29, I provide a timing circuit or timing means for supplying to this circuit a voltage to control the energization of the welding circuit 1 by controlling the conduction of electric valve means 26 and 27. More particularly, I provide a source of direct current including a positive conductor 39 and a negative conductor or terminal 40. I connect across the conductors 39 and 40 a voltage divider including resistances 41-45, inclusive. If desired, a filtering capacitance 46 may be connected across resistance 41, and a separate voltage divider comprising a resistance 47 may be connected across resistance 42. Resistances 42 and 47 are provided with adjustable contacts 48 and 49, respectively, the functions of which will be explained hereinafter.

I provide a pair of parallel connected electric circuits energized from points of the voltage divider including resistances 41-45 which are intermediate the terminal connections, and each of which comprises a serially connected impedance element and an electric discharge device. More particularly, one electric circuit includes a serially connected resistance 50 and an electric discharge device 51, and the other of which includes a serially connected resistance 52 and an electric discharge device 53. If desired, additional current limiting means, such as resistances 54 and 55, may be connected in series relation with electric discharge devices 51 and 53, respectively. The electric discharge devices 51 and 53 are preferably of the type employing an ionizable medium, such as a gas or a vapor, and each comprises an anode 56, a cathode 57 and a control grid 58. Commutating means, such as a capacitance 59, is connected across the parallel connected electric

circuits and serves to effect transfer of the current from a conducting electric circuit to a non-conducting electric circuit when its electric discharge device is caused to conduct current. The grid circuits for electric discharge devices 51 and 53 include means which impress on the grids 58 positive impulses of voltage to render discharge devices 51 and 53 conducting at precisely determinable instants of time. This means may comprise a saturable peaking device, such as a peaking transformer 60 having secondary windings 61 and 62 which are connected in circuit with grids 58 of discharge devices 51 and 53, respectively. The peaking transformer 60 may be energized from the bridge circuit described above, and may have its primary winding 63 connected to be energized through filtering means such as a capacitance 64, an inductance 65 and a resistance 66. Resistance 66 may be made adjustable to control the magnitude of the voltages of peaked wave form induced in secondary windings 61 and 62, and inductance 65 may be made adjustable in order to control the phase of the voltages of peaked wave form relative to the voltage of circuit 15. The phase of the output voltage of secondary windings 61 and 62 is also controllable by means of resistances 34 and 35.

As a means for impressing on the grids 58 of the electric discharge devices 51 and 53 negative unidirectional biasing potentials, I provide a pair of capacitances 67 and 68 which are crisscrossed from resistances 50 and 52 to grids 58 of discharge devices 53 and 51, respectively. Capacitances 67 and 68 are charged by means of a pair of unidirectional conducting paths which may be provided by an electric valve 69 connected between capacitances 67 and 68 and a relatively negative point 70 of the voltage divider including resistances 41—45. The electric valve 69 may be of the type having an electrically common cathode 71 and separate anodes 72 and 73 which are, respectively, connected to capacitances 67 and 68. As will be more fully explained in connection with the operation of the system, the electric valve 69 limits the minimum value of negative unidirectional biasing potential impressed on control grids 58 of discharge devices 51 and 53, thereby definitely establishing that value of negative biasing potential which affords the maximum precision in the time of initiation of current conduction by electric discharge devices 51 and 53.

It will be noted that circuit 29, which constitutes an output circuit for the timing circuit, comprises a conductor 74 which is connected to one of the parallel-connected electric circuits such as that including the discharge device 53. More particularly, conductor 74 may be connected directly to anode 56 of discharge device 53. Conductor 75 of the output circuit 29 may be connected to a point of relatively fixed potential, such as conductor 39 of the direct current source. When the electric discharge device 53 conducts current, the potential of conductor 74 is lowered and when the electric discharge device 53 is non-conducting its potential is raised. Windings 61 and 62 are poled so that the voltages impressed on grids 58 are in phase. These voltages, acting in conjunction with the timing circuits connected to grids 58, operate to render the electric discharge devices 51 and 53 conducting alternately. I provide means for controlling the relative duration of the periods of conduction of electric discharge devices 51 and 53. This means comprises circuits connected between the grid circuits

for the electric discharge devices 51 and 53 to control the rate at which the capacitances 68 and 67 discharge, thereby controlling the rate at which the potentials impressed on grids 58 rise. For example, I connect between capacitance 67 and a relatively positive point of the voltage divider including resistances 41—45, such as the adjustable contact 48 of resistance 42, means for controlling the time constant of the discharge circuit for this capacitance. A variable impedance element, such as a variable resistance 76, is connected in the discharge circuit for the capacitance 67. This discharge circuit includes the anode-cathode circuit of discharge device 51. In like manner, a variable impedance element, such as a variable resistance 77, may be connected in circuit with the capacitance 68 and grid 58 of electric discharge device 51 to control the time constant of the discharge circuit for this capacitance. Of course, as will be explained hereinafter, the discharge circuit for capacitance 68 includes the anode-cathode circuit of the electric discharge device 53.

As a means for initiating operation of the timing circuit, I provide circuit controlling means such as a relay 78 which may include an actuating coil 79 and may include contacts 80, 81 and 82. Contacts 81 are normally open and are connected in the anode-cathode circuit of electric discharge device 51. Contacts 82 are employed when the system is set for a spot welding operation, that is when the control circuit is preset or established to produce a single impulse of control voltage. Normally closed contacts 82 are employed to close a discharge path for capacitance 68 when the system is set for spot welding operation.

Means are provided for presetting the timing means for producing either a single impulse of control voltage or for producing a series of impulses of control voltage. This means may comprise a switch 83 having contacts 84 and 85 the former of which connect the grid 58 of discharge device 51 to the negative terminal 40 of the direct current source through a high ohmic resistance 86, thereby permitting only a single interval of conduction by the electric discharge device upon a single circuit controlling operation of relay 78. The resistance 86 serves to build up or maintain on grid 58 of discharge device 51 a negative unidirectional biasing potential through contacts 81 of sufficient magnitude to overcome the effect of the voltage of peaked wave form produced by secondary winding 61 of transformer 60. When contact 85 of switch 83 is closed, the timing means produces a series of impulses of control voltage, to render the electric discharge devices 51 and 53 conducting alternately, the period of conduction by the devices being determined by the adjustment of the circuits including resistances 76 and 77, contacts 48 and 49, and resistances 50 and 52.

The operation of the embodiment of my invention shown in Fig. 1 of the drawings will be explained by considering the system when it is operating to effect energization of the welding circuit at predetermined recurring intervals of time. For this type of operation, the switch 83 is moved to close its contact 85. Upon energization of the direct current source including conductors 39 and 40, the electric discharge device 53 is rendered conducting by virtue of the voltage of peaked wave form impressed on its grid 58 by means of secondary winding 62 of transformer 60. Inasmuch as the electric discharge device

53 is of the type employing an ionizable medium, upon being rendered conducting this discharge device continues to conduct current until its cathode is rendered positive in potential relative to its anode when electric discharge device 51 is rendered conducting.

By conducting current, the electric discharge device 53 lowers the potential of conductor 74 thereby impressing on the grids 28 of electric valve means 26 and 27 a negative unidirectional biasing potential sufficient to maintain these electric valve means nonconducting. In other words, the magnitude of this potential is sufficient to overcome the effect of the peaked voltage produced by secondary winding 31. The electric discharge device 51 at this time is prevented from operating due to the fact that its anode-cathode circuit is open, the contacts of relay 78 being open when the relay 78 is deenergized.

Initiation of the operation of the timing means, and the translating circuit which energizes the welding circuit, is accomplished by energizing actuating coil 79 of relay 78. Closure of contacts 80 of relay 78 does not necessarily initiate conduction by electric discharge device 51 unless it so happens that the contacts 80 close at a time coincident with the occurrence of the positive voltage of peaked wave form produced by secondary winding 61 of transformer 60. In this manner the time of initiation of conduction of the discharge device 51 and hence the time of initiation of the impulse of control voltage are synchronized with respect to the voltage of alternating current circuit 15, or the alternating current supply circuit 2.

Upon being rendered conducting the discharge device 51, through the operation of the commutating capacitance 59, effects transfer of current from the discharge device 53 to the discharge device 51. This transfer of current is obtained by virtue of the fact that the left-hand plate of capacitance 59 was charged to a positive potential during the interval in which discharge device 53 conducted current, so that when discharge device 51 is rendered conducting the cathode of discharge device 53 is raised in potential with respect to the anode thereby effecting an interruption of the current flow through discharge device 53.

During the interval of time within which discharge device 53 conducted current, capacitance 67 was charged from a direct current source through a circuit including resistance 41, resistance 54, part of resistance 50, capacitance 67, anode 72 and cathode 71 of electric valve 69 and resistance 45 to produce a negative unidirectional biasing potential, and to impress this potential on grid 58 of discharge device 53. This negative potential at that time was ineffective to control the conductivity of discharge device 53 because its anode-cathode circuit was continuously energized.

At the time the discharge device 51 is rendered conducting and during an interval thereafter, the capacitance 67 discharges through a circuit including the lower portion of resistance 50, contacts 80 of relay 78, the anode-cathode circuit of discharge device 51, resistance 43, resistance 42 and resistance 76. The time constant of this last defined discharge circuit is controllable or adjustable by means of any of the elements including resistances 50, 42 or 76. Of course, inasmuch as the last-mentioned elements are connected through the voltage divider to the direct current source, the time constant

of the discharge circuit is in a measure controlled by the voltage divider although the last-mentioned elements are the principal factors in controlling the value of the time constant. In other words, by the adjustment of this discharge circuit, the rate at which the biasing potential impressed on grid 58 of discharge device 53 rises may be determined, thereby determining the rate at which the potential level of the grid 58 is raised and, hence, controlling the time at which discharge device 53 is subsequently rendered conducting to end the impulse of control voltage applied to circuit 29.

Electric valve 69 and more particularly the right-hand unidirectional conducting path including anode 72 and cathode 71 limit the minimum value of biasing potential which is impressed on grid 58 of discharge device 53, inasmuch as this unidirectional conducting path is connected between resistance 76 and a relatively negative point of the voltage divider. By so limiting the minimum value of the biasing potential, greater accuracy is obtained by establishing a predetermined definite level against which the peaked voltage of secondary winding 62 must operate.

When the biasing potential rises to a value sufficiently small established by the electric valve 69, the voltage of peaked wave form produced by secondary winding 62 becomes operative to render the discharge device 53 conducting, thereby effecting commutation of the current from the discharge device 51 to the discharge device 53. This operation is effected by the capacitance 59 which during the period of conduction by discharge device 51 was charged so that its right-hand plate was positive relative to the left-hand plate. During the period of conduction by electric discharge device 51, capacitance 68 was charged to impress a negative biasing potential on grid 58 of discharge device 51 through a circuit including resistances 41, 55 and 52, capacitance 68, anode 73 and cathode 71 of electric valve 69 and resistance 45. After the discharge device 53 is rendered conducting, capacitance 68 is discharged through a circuit including resistance 52, the anode-cathode circuit of discharge device 53, resistances 43 and 47, contact 85 and resistance 77. The biasing potential decreases at a rate determined principally by the time constant of this last defined discharge circuit, and the minimum value of the biasing potential is established by the left-hand unidirectional conducting path of electric valve 69. The time constant of this circuit, therefore, determines the duration of the period of conduction by discharge device 53 and, hence, determines the duration of the more negative portion of the periodic voltage supplied to the output circuit 29. So long as the relay 78 is energized, the electric discharge devices 51 and 53 conduct current alternately to produce a periodic timing voltage which is correlated or synchronized with respect to the voltage of the alternating current circuits 15 or 2. The relative and absolute duration of the relatively positive and negative portions of the timing voltage may be controlled or adjusted by the means described immediately preceding.

The operation of the timing means may be more fully explained by referring to the operating characteristics shown in Fig. 2. The curves there illustrated are particularly identified with respect to the elements of the timing means. If it be assumed that contacts 80 of relay 78 close at time *a*, positive voltage is applied to the anode of the discharge device 51 but inasmuch as the

time of closure is not coincident with the occurrence of a positive impulse of voltage produced by secondary winding 61, the discharge device 51 will not be initiated in its conduction until time b. The electric discharge device 51 then conducts current during the interval b—c, and the discharge device 53 during this same interval is maintained nonconducting. At time c, the discharge device 53 is rendered conducting and current is commutated from discharge device 51. Consequently, discharge device 53 conducts current during the interval of time c—d.

It will be noted that by virtue of electric valve 69, the biasing potential impressed on grid 58 of the discharge device 51 and the grid 58 of discharge device 53 are maintained at predetermined minimum values which are correlated with respect to the magnitude of the voltage of peaked wave form in order to obtain the desired precision in the control of the time at which the respective discharge devices are rendered conducting. The bottom set of curves of Fig. 2 represent the effect of the timing means on the operation of the electric valves 25 and 27 and consequently represent the controlling effect on the electric valve means 4, 5 and 10, 11. During the interval b—c within which the electric discharge device 51 conducts current, the voltage of circuit 29 is rendered less negative by an amount sufficient to render electric valves 25 and 27 conducting and, in turn, to render the electric valve means 4, 5 and 10 and 11 conducting. Of course, it will be appreciated that the electric valve means 4 and 5 conduct current alternately during intervals of time displaced 180 electrical degrees so that alternating current is transmitted to the transformer 3 and welding circuit 1.

Considering now the operation of the control circuit 14 when the electric valves 26 and 27 are rendered conducting by the superposition of the blocked or square timing wave produced by the timing means on the periodic voltage of peaked wave form produced by transformer 30, these electric valves conduct current to effect energization of transformers 24 and 25 alternately, thereby raising the potential of grids 12 of control electric valve means 10 and 11, causing these electric valve means to conduct current alternately and consequently effect energization of the immersion-igniter control members 6. The impulses of voltage produced by the impulse energization of transformers 24 and 25 overcome the effects of the alternating hold-off voltages supplied by transformer secondary windings 19 and 20.

I have found that satisfactory operation of the system is obtained when inductances 37 and 65 are adjusted so that the phase of the peaked voltages produced by transformer 60 lags the voltages produced by transformer 30 by an angle in the neighborhood of 10 or 15 electrical degrees. This adjustment assures that the rounded front of the substantially square voltage wave shown in Fig. 2 does not prevent the desired operation of the system. In other words, by this adjustment the system is made to operate on the substantially flat top portions of the square voltage wave. Adjustment of inductance 37 also controls the amount of energy or the magnitude of the current transmitted to welding circuit 1 by controlling the time at which current conduction is initiated during the various positive and negative half cycles of the voltage of alternating current circuit 2. As the phase of the output voltage of transformer 30 is advanced toward the

beginning of the positive half cycles, the amount of current transmitted to welding circuit 1 is increased and, conversely, as the phase of this peaked voltage is retarded the amount of current transmitted to welding circuit 1 is decreased.

One important advantage of the timing means which I provide is that it assures synchronous operation of the system. It not only assures synchronization of the time of occurrence of the less negative or more positive portion of the timing voltage, but it also assures synchronization of the termination of the less negative portion and the initiation of the more negative portion.

Another advantage of the timing means which I provide is that the capacitances 67 and 68 are charged from the direct current supply circuit through the electric valve 69 instead of using the grid-cathode circuits of the discharge devices as charging circuits. This feature permits the use of grid circuits of higher resistance in combination with peaking transformers of smaller size and rating without incurring or involving undesirable effects due to transients in the grid circuits, and without impairing the rapidity with which the timing capacitances 67 and 68 may be recharged.

If it is desired to obtain a single energization of the welding circuit 1 in response to a single circuit controlling operation of relay 78, switch 83 is moved to the upper position wherein contact 84 is closed. Under this adjustment, electric discharge device 51 conducts current only once upon a single closure of relay 78 and after a single conduction thereof a negative hold-off voltage is impressed on grids 58 of discharge device 51 through a circuit including resistance 86 and contacts 81 of relay 78. This latter mentioned biasing potential is sufficiently great to render ineffective the peaked voltage produced by secondary winding 61. Stated in other words, when the contacts 81 of relay 78 are closed, a negative charge is maintained on the capacitance 68. Another impulse of timing voltage may be produced by de-energization and subsequent re-energization of actuating coil 79. During this operation, the capacitance 68 is permitted to discharge through contacts 82 which are closed when relay 79 is deenergized.

While I have shown and described my invention as applied to a particular system of connections and as embodying various devices diagrammatically shown, it will be obvious to those skilled in the art that changes and modifications may be made without departing from my invention, and I, therefore, aim in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination, an alternating current circuit, a load circuit, electric translating apparatus connected between said circuits and comprising means including electric valve means for controlling the energization of said load circuit, said electric valve means including a control member, means for impressing on said control member a periodic voltage, means for superimposing on said periodic voltage a variable control voltage to control the period of energization of said load circuit and comprising a source of direct current, means connected to said source and comprising a pair of parallel connected electric circuits each including in series relation a resistance

and an electric discharge device having a grid, communicating means connected across said parallel connected electric circuits, means connected to said grids for controlling the relative periods of conduction of said pair of electric discharge devices, means for introducing in said grid circuits negative unidirectional biasing potentials of predetermined minimum value, means for impressing on said grids alternating voltages of peaked wave form of a value sufficient to overcome the effect of said minimum biasing potentials, and means for independently adjusting the phase of the periodic voltage and said voltages of peaked wave form.

2. In combination, an alternating current circuit, a load circuit, electric translating apparatus connected between said circuits and comprising electric valve means for controlling the energization of said load circuit, said electric valve means having a control member, means for impressing on said control member a periodic voltage of peaked wave form, means for superimposing on said periodic voltage of peaked wave form a control voltage of substantially rectangular wave form to establish the intervals of time within which said periodic voltage of peaked wave form is effective and comprising a source of direct current, a pair of parallel connected electric circuits energized from said source and each including in series relation a resistance and an electric discharge device having a grid, means connected to said grids for controlling the relative periods of conduction of said discharge devices thereby controlling the duration of the control voltage, means connected to the grids of said discharge devices for impressing thereon periodic voltages of peaked wave form to cause said discharge devices to conduct current, and means for adjusting the phase of the last mentioned periodic voltages of peaked wave form to lag the first mentioned periodic voltage of peaked wave form.

3. In combination, an alternating current circuit, a load circuit, electric translating apparatus connected between said circuits and comprising electric valve means for controlling the energization of said load circuit, said electric valve means having a control member, means for impressing on said control member a periodic voltage, means for superimposing on said periodic voltage a substantially square wave negative unidirectional control voltage having during one interval of time a predetermined negative value and during a subsequent interval of time a predetermined larger negative value and comprising a source of direct current, a pair of parallel connected electric circuits energized from said source and each including in series relation a resistance and an electric discharge device having a grid, a commutating capacitance connected across said parallel connected electric circuits, means for rendering said discharge devices conducting alternately comprising means for impressing on said grids periodic voltages of peaked wave form, means for controlling the relative periods of conduction of said discharge devices to control the relative durations of the portions of said control voltage, means for impressing predetermined minimum negative unidirectional biasing potentials on said grids, and means for retarding the phase of said periodic voltages of peaked wave form relative to the first mentioned periodic voltage in order that the controlling operation of said control voltage is obtained on

the completely flat portion of the square wave control voltage.

4. In combination, a source of direct current having positive and negative terminals, a pair of electric circuits energized from said source and each comprising in series relation an impedance element and an electric discharge device having a grid, an impedance element connected between said pair of electric circuits and one terminal of said source, commutating means connected across said pair of electric circuits, circuits connected to said grids for rendering said pair of electric circuits conducting selectively so that when one electric discharge device conducts current the other electric discharge device is rendered non-conducting by operation of said commutating means, and means comprising a unidirectional conducting device connected between a point of the last mentioned impedance element and the circuits for said grids to limit the value of unidirectional biasing potential impressed thereon.

5. In combination, a source of direct current having positive and negative terminals, an output circuit, and means connected between said circuits for supplying to said output circuit a voltage of predetermined duration and including a pair of electric circuits each comprising in series relation a resistance and an electric discharge device having a grid, a resistance connected in series relation with said pair of electric circuits and connected to one terminal of said source, commutating means comprising a capacitance connected across said pair of electric circuits, a pair of crisscrossed grid circuits each comprising a capacitance and connected between the grid of one of the discharge devices and the resistance in series relation with the other discharge device, a pair of peaking means each associated with a different one of the discharge devices for impressing on the grids voltages of peaked wave form, and means comprising a pair of unidirectional conducting paths connected between a point of the resistance in series with said pair of electric circuits and the peaking means for impressing on the grids a negative unidirectional biasing potential of predetermined minimum value.

6. In combination, a direct current circuit, an output circuit, and means connected between said circuits for supplying to said output circuit a control voltage of predetermined duration and including a pair of electric circuits each comprising in series relation an impedance element and an electric discharge device having a grid, commutating means connected across said electric circuits, means for impressing on said grids a negative unidirectional biasing potential tending to maintain said electric discharge devices non-conducting and comprising a pair of unidirectional conducting paths each connected to a different one of said grids and both connected to one terminal of said direct current circuit through an impedance element and means for superimposing on said biasing potential a voltage of peaked wave form sufficient to overcome the effect of said biasing potential and for rendering one of said discharge devices conducting thereby effecting commutation of current from one of said discharge devices to the other discharge device by operation of said commutating means.

7. In combination, a direct current circuit having positive and negative terminals, an output circuit, means connected between said circuits

for supplying to said output circuit a control voltage of predetermined duration and including a pair of electric circuits each comprising in series relation an impedance element and an electric discharge device having a grid, commutating means comprising a capacitance connected across said electric circuits, means comprising a pair of crisscrossed circuits connected between said electric circuits and said grids and each comprising a capacitance, means comprising a unidirectional conducting device having a pair of electric discharge paths for impressing on said grids a negative unidirectional biasing potential of predetermined minimum value and means for superimposing on said biasing potential a voltage of peaked wave form sufficient to overcome the effect of the biasing potential.

8. In combination, a direct current circuit, an output circuit, and means connected between said circuits for supplying to said output circuit a control voltage of predetermined duration and including a pair of electric circuits each comprising in series relation an impedance element and an electric discharge device having a grid, means comprising an impedance element connected between one terminal of said direct current circuit and the grid of one of the electric discharge devices, a pair of crisscrossed circuits connected between said impedance elements and the grids of the electric discharge devices in opposite electric circuits, and a unidirectional conducting device connected between said grids and the last mentioned impedance element for impressing on the grids a negative biasing potential.

9. In combination, a source of direct current comprising positive and negative conductors, an output circuit, and means connected between said circuits for supplying to said output circuit a voltage of predetermined duration comprising a pair of electric circuits energized from said source and each comprising in series relation a resistance and an electric discharge device having a grid, a pair of crisscrossed grid circuits each comprising a capacitance connected between the grid of a different one of the discharge devices and the resistance in the other electric circuit, a resistance connected in series relation with said pair of electric circuits and connected to said negative terminal, means comprising a unidirectional conducting device connected between the circuits for said grids and a point of the last mentioned resistance for charging said capacitances, means connected between said positive terminal and the grid circuits for providing a discharge path for said capacitances, said unidirectional conducting device serving to control the discharge of said capacitances to limit the minimum value of the negative unidirectional biasing potential impressed on said grids, commutating means connected across said electric circuits and means for superimposing on said negative unidirectional biasing potential voltages of peaked wave form to render said electric discharge devices conducting alternately.

10. In combination, a source of direct current comprising positive and negative terminals, an output circuit, and means connected between said circuits for supplying to said output circuit a periodic voltage having positive and negative portions of predetermined duration and comprising a pair of electric circuits each including a resistance in series relation with an electric discharge device, said electric discharge devices each having a control grid, commutating means connected across said electric circuits, means connected to

the grids for impressing thereon voltages of peaked wave form to render said discharge devices conducting alternately, means for controlling the relative periods of conduction of said

5 electric discharge devices thereby controlling the relative duration of said positive and negative portions of said periodic voltage comprising a pair of crisscrossed grid circuits each connected between the grid of a different discharge device and the resistance associated with the other discharge device and each comprising a capacitance, a resistance connected between said pair of electric circuits and said negative terminal, a pair of unidirectional conducting paths connected between a point of the last mentioned resistance and said capacitances to provide a path for charging said capacitances to produce negative unidirectional biasing potentials, means for discharging said capacitances to control the period of time during which each discharge device is maintained nonconducting after the other discharge device has been rendered conducting and means for selectively controlling said electric discharge devices to produce either a single impulse of control voltage or a series of impulses of control voltage.

11. In combination, a source of direct current comprising positive and negative terminals, an output circuit, means connected between said circuits for supplying to said output circuit a control voltage of predetermined duration and including a pair of electric circuits each comprising in series relation a resistance and an electric discharge device having a grid, commutating means connected across said electric circuits, means for impressing on said grids negative unidirectional biasing potentials and comprising a pair of circuits each including in series relation a capacitance and a unidirectional conducting path and each connected between a point of said resistances and a negative terminal of said source, said unidirectional conducting paths serving to limit the minimum value of negative unidirectional biasing potentials impressed on said grids, means connected to said grids for impressing thereon voltages of peaked wave form having a value sufficient to overcome the minimum value of said voltage of said unidirectional biasing potential, means for effecting discharge of said capacitances thereby reducing the biasing potential impressed on the grids of the discharge devices and comprising means for controlling the rate of decay of said biasing potential, said unidirectional conducting paths serving to limit the minimum value of said biasing potential to that value which just permits the voltages of peaked wave form to render the electric discharge devices conducting.

12. In combination, a source of direct current having positive and negative terminals, an output circuit, and means connected between said circuits for supplying to said output circuit a control voltage of predetermined duration comprising a voltage divider connecting said positive and negative terminals, a pair of parallel connected electric circuits energized from points of said voltage divider intermediate the terminal connections and each comprising in series relation a resistance and an electric discharge device having a grid, grid circuits for said discharge devices, a pair of capacitances each connected from the grid circuit of a different discharge device to the resistance associated with the other discharge device, means for charging said capacitances to impress on the grids negative uni-

directional biasing potentials and comprising a pair of unidirectional conducting paths connected between the grid circuits and a relative negative point of said voltage divider, commutating means connected across said parallel electric circuits, means for rendering said discharge devices conducting alternately comprising means for superimposing on said biasing potentials voltages of peaked wave form, and means connected between relatively positive portions of said voltage divider and the grid circuits for said discharge devices to afford discharge paths for said capacitances through the electric discharge devices, said unidirectional conducting paths serving to limit the minimum value of said biasing potentials.

13. In combination, a source of direct current comprising positive and negative terminals, an output circuit, and means connected between said circuits for supplying to said output circuit a periodic voltage having positive and negative portions of predetermined duration, a voltage divider connected across said positive and negative terminals, a pair of parallel connected electric circuits energized from points of said voltage divider intermediate the terminal connections and each comprising in series relation a resistance and an electric discharge device including an anode, a cathode and a control grid, a pair of capacitances each connected between the grid circuit for a different one of said discharge devices and the resistance associated with the other discharge device, means for charging said capacitances to impress on the grids negative unidirectional biasing potentials and comprising a pair of unidirectional conducting paths each connected from a different grid circuit to a relatively negative point of said voltage divider, means for controlling the periods of conduction of said electric discharge devices and for controlling thereby the relative duration of the positive and negative portions of said control voltage and including means for discharging said capacitances through the anode-cathode circuits of said discharge devices and including means connected between the grid circuits and relatively positive points of said voltage divider and means connected in the discharge circuits for controlling the time constants thereof.

14. In combination, a source of direct current having positive and negative terminals, an output circuit, and means for energizing said output circuit comprising a voltage divider connected across said positive and negative terminals, a pair of parallel connected electric circuits energized from points of said voltage divider intermediate the terminal connections and each comprising in series relation a resistance and an electric discharge device having a grid, commutating means connected across said parallel circuits, means for impressing negative unidirectional biasing potentials on said grids and comprising a pair of capacitances each connected in circuit with a different one of said grids and the resistance associated with the other electric discharge device and including a unidirectional conducting path connected between the associated capacitance and a relatively negative point of said voltage divider, means for superimposing on said negative biasing potentials voltages to render said discharge devices conducting alternately, discharge paths for said capacitances including means connected to the grids and energized from relatively positive points of said voltage divider, said last mentioned means

including means for controlling the periods of conduction of said electric discharge devices, and means connected to the grid of one of the discharge devices for controlling said discharge device to produce a single impulse of positive voltage or for producing a series of impulses of positive voltage.

15. In combination, a source of direct current having positive and negative terminals, an output circuit, and means connected between said circuits for supplying to said output circuit a control voltage and including a voltage divider connected across said terminals, a pair of parallel connected electric circuits each including in series relation a resistance and an electric discharge device having a grid, commutating means connected across said parallel connected circuits, grid circuits for said discharge devices and each comprising a capacitance connected in circuit with the grid and the resistance associated with the other electric discharge device, means for charging said capacitances to impress on the grids negative unidirectional biasing potentials and comprising a pair of unidirectional conducting paths connected between the grid circuits and a relatively negative point of said voltage divider, discharge circuits for said capacitances including means connected to relatively positive points of said voltage divider, and circuit controlling means comprising contacts in series relation with one of the discharge devices normally to maintain said one discharge device nonconducting and for initiating generation of said control voltage.

16. In combination, a source of direct current including positive and negative terminals, an output circuit, means connected between said circuits for supplying a control voltage to said output circuit and including a voltage divider connected across said terminals, a pair of parallel connected electric circuits energized from points of said voltage divider intermediate the terminal connections and each including in series relation a resistance and an electric discharge device having a grid, the relative periods of conduction of said discharge devices serving to produce relatively positive and negative portions of said control voltage, commutating means connected across said parallel connected electric circuits, a pair of grid circuits for said discharge devices and each including a capacitance connected in circuit with the associated grid and the resistance associated with the other discharge device, means connected in said grid circuits for impressing on the grids impulses of voltage of peaked wave form, means for charging said capacitance to impress on the grids negative unidirectional biasing potentials comprising a pair of unidirectional conducting paths connected between the grid circuits and a relatively negative point of said voltage divider, discharge circuits for said capacitances for controlling the relative periods of conduction of said discharge devices and comprising means connected between said grid circuits and relatively positive points of said voltage divider, and circuit controlling means comprising a contact in series relation with said one electric discharge device for initiating production of the impulses of control voltage.

17. In combination, a source of direct current including positive and negative terminals, an output circuit, means connected between said circuits for supplying a control voltage to said output circuit and including a voltage divider connected across said terminals, a pair of par-

allel connected electric circuits energized from points of said voltage divider intermediate the terminal connections and each including in series relation a resistance and an electric discharge device having a grid, the relative periods of conduction of said discharge devices serving to produce relatively positive and negative portions of said control voltage, commutating means connected across said parallel connected electric circuits, a pair of grid circuits for said discharge devices and each including a capacitance connected in circuit with the associated grid and the resistance associated with the other discharge device, means connected in said grid circuits for impressing on the grids impulses of voltage of peaked wave form, means for charging said capacitances to impress on the grids negative unidirectional biasing potentials comprising a pair of unidirectional conducting paths connected between the grid circuits and a relatively negative point of said voltage divider discharge circuits for said capacitance for controlling the relative periods of conduction of said discharge devices and comprising means connected between said grid circuits and relatively positive points of said voltage divider, and circuit controlling means comprising contacts in series relation with one of said discharge devices for controlling the energization of the anode-cathode circuit of said one discharge device and including a resistance connected between the grid circuit therefor and said negative terminal to maintain said one discharge device non-conducting after a single interval of conduction thereof.

18. In combination, a source of direct current

including positive and negative terminals, an output circuit, means connected between said circuits for supplying a control voltage to said output circuit and including a voltage divider connected across said terminals, a pair of parallel connected electric circuits energized from points of said voltage divider intermediate the terminal connections and each including in series relation a resistance and an electric discharge device having a grid, the relative periods of conduction of said discharge devices serving to produce relatively positive and negative portions of said control voltage, commutating means connected across said parallel connected electric circuits, a pair of grid circuits for said discharge devices and each including a capacitance connected in circuit with the associated grid and the resistance associated with the other discharge device, means connected in said grid circuits for impressing on the grids impulses of voltage of peaked wave form, means for charging said capacitances to impress on the grids negative unidirectional biasing potentials and comprising a pair of unidirectional conducting paths connected between the grid circuits and a relatively negative point of said voltage divider, discharge circuits for said capacitances for controlling the relative periods of conduction of said discharge devices and comprising means connected between said grid circuits and relatively positive points of said voltage divider, and means for controlling said discharge devices to produce a single impulse of control voltage or to produce a series of impulses of control voltage.

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