

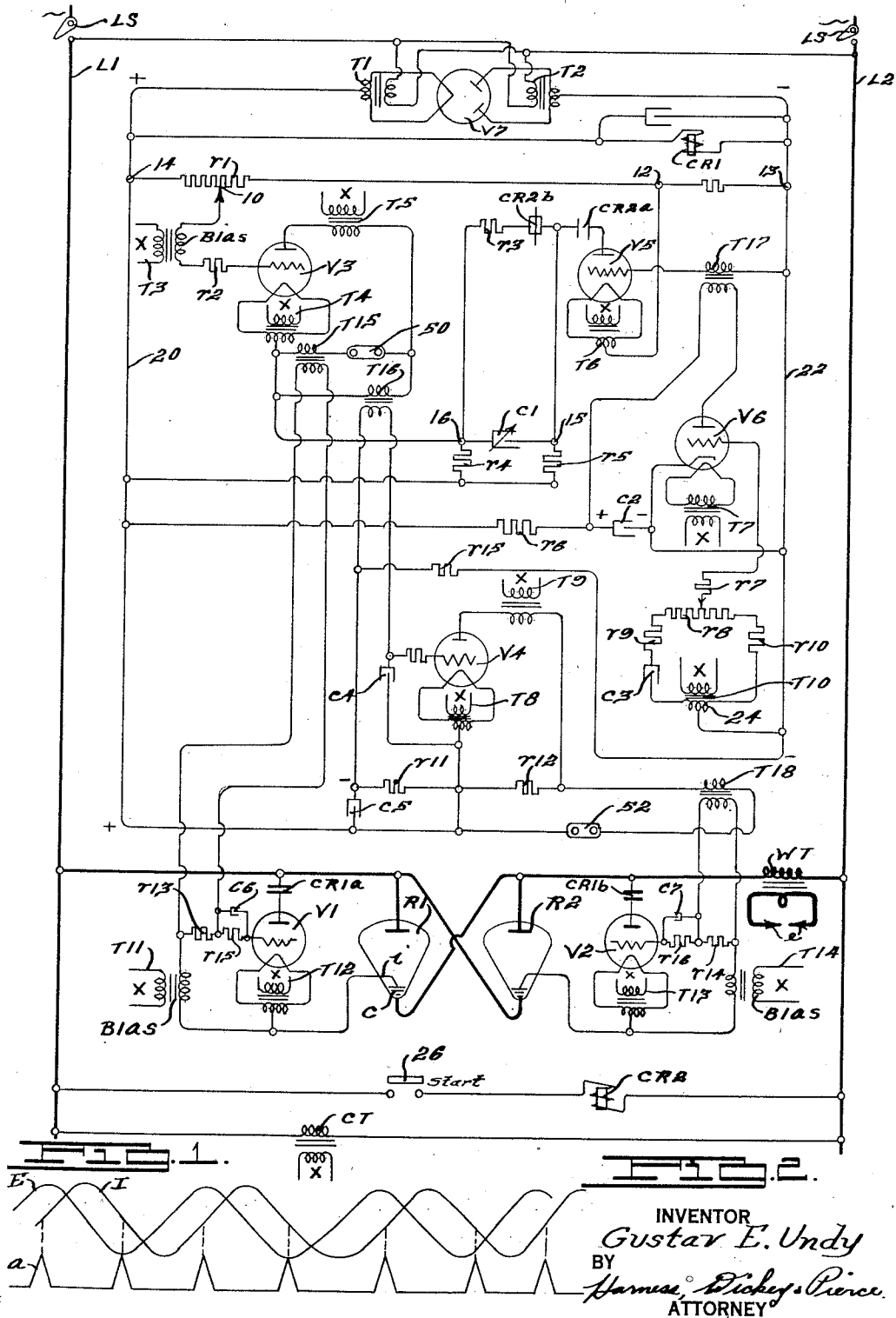
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TIMING CONTROL SYSTEM

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TIMING CONTROL SYSTEM

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The present invention relates to timing control systems and in particular provides an improved control system especially adapted for, but not limited to, use in connection with resistance welding systems of the synchronous type.

The principal objects of the present invention are to provide a system of the above generally indicated type, which is simple in arrangement and which is efficient and reliable in operation; to provide such a system incorporating means to enable a random closure of a starting device to cause closure of an associated load circuit at a point which is precisely located relative to the periodicity of an alternating current supply circuit, and further embodying means to precisely control the period that the work circuit remains closed; to provide such a system wherein the starting point of a timing interval is determined by subjecting the grid circuit of an electric valve to peaked impulses derived from an oscillator circuit of the saw-tooth type; to provide such a system wherein the over-all length of each timing period is determined by the time required to charge a condenser to a predetermined degree; and to generally improve the operation and arrangement of timing control systems.

With the above as well as other objects in view, which appear in the following description and in the appended claims, a preferred but illustrative embodiment of the invention is shown in the accompanying drawing, throughout the several views of which corresponding reference characters are used to designate corresponding parts and in which:

Figure 1 is a diagrammatic view of a control system embodying the invention; and

Fig. 2 is a diagrammatic view illustrating the time relations between certain of the operations which take place in connection with the system of Fig. 1.

It will be appreciated from a complete understanding of the present invention that in a generic sense the improvements thereof are applicable to a wide variety of electrical control systems adapted for a wide variety of specific purposes. A preferred use of the present invention is in connection with resistance welding systems of the so-called synchronous type and in an illustrative but not in a limiting sense, the invention is so disclosed herein.

Referring first to Fig. 1, the primary winding of a usual welding transformer WT is arranged to receive power from a usual alternating current source represented by the line conductors L1 and L2. The secondary winding of the welding trans-

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former WT is illustrated as connected to the opposed electrodes *e* of a resistance welding machine which may be, for example, a spot welding machine. The flow of current to the primary winding of the welding transformer WT is controlled by a pair of reversely connected main rectifiers R1 and R2, which, as shown, are directly interposed in the circuit of the primary winding of the transformer. Rectifiers R1 and R2 may be of any suitable type, but are illustrated as being of a mercury pool type, such as those sold commercially under the trade name "ignitrons." In accordance with conventional practice, rectifiers R1 and R2 are provided, respectively, with firing valves V1 and V2, which may be of the usual three-element discontinuous type. Valves V1 and V2 are normally biased to a non-conductive condition by the associated biasing transformers T11 and T14, which, in combination with condensers C6 and C7 and resistors r15 and r16, apply negative biases to the grids of valves V1 and V2.

The firing valves V1 and V2 are disposed to be rendered conductive (so as to fire the main rectifiers R1 and R2) at a selected point in each corresponding half cycle of a desired succession of cycles by a pair of timing valves V3 and V4. Valve V3 is coupled to the grid circuit of valve V1 by means of a transformer T15, whereas valve V4 is coupled to the grid circuit of valve V2 by means of transformer T18. Valves V3 and V4 may be regarded, for purposes of description, as being connected to pass current during the positive and negative half cycles, respectively, and consequently rectifier R1 is fired in each positive half cycle in which valve V3 passes current, and rectifier R2 is fired in each negative half cycle in which valve V4 passes current. In accordance with the inventions disclosed in the copending applications of C. J. Collom, Serial No. 222,825, filed August 3, 1938, now Patent Number 2,289,320, and the present applicant, Serial No. 402,922, filed July 18, 1941, now Patent Number 2,401,780, valves V3 and V4 are interconnected in such a way that each operation of valve V3, during a positive half cycle, is followed by an operation, in the next negative half cycle, of valve V4. Each timing interval of the system thus comprises an even number of half cycles, each such timing interval beginning with a positive half cycle and each such timing interval ending with a negative half cycle.

The over-all length of each timing period is governed by the adjustable timing interval of a main condenser C1, which is coupled to the grid

cathode circuit of valve V3, and becomes effective, when charged to a predetermined degree, to render the grid of valve V3 negative with respect to the cathode. This action blocks the passage of further impulses through valve V3 and interrupts the timing period.

The initial firing of valve V3 is controlled by a starting valve V5, the grid of which is brought to a conducting value once in each positive half cycle of the source of supply. This control is accomplished by a transformer T17, which is connected in the output circuit of a conventional saw-tooth oscillator comprising the valve V6.

As will be understood, valves V3 through V8 may be and preferably are of the usual three-element discontinuous type. It will be noted, also, that direct current for certain of the control circuits is furnished through a usual full-wave rectifying network comprising the usual rectifier V7. It is believed that the remaining details of the system may best be understood from a description of the operation thereof.

The system may be conditioned for operation by closing the usual line switches LS, so as to energize the line conductors L1 and L2. This action immediately energizes transformers T1 and T2, associated with the filament and plate circuits of the rectifier V7, and also energizes the primary winding of the control transformer CT. The energization of transformers T1 and T2 enables the application, through rectifier V7, of a direct current potential across the direct current line conductors 20 and 22. The energization of the control transformer CT enables it to energize transformers T3 through T14, which connections are indicated by the reference character *x* applied to the secondary terminals of transformer CT and to the primary terminals of transformers T3 through T14. Transformers T4, T5, T7, T8, T12 and T13 are associated with the cathodes of valves V3, V5, V6, V4, V1 and V2, respectively, and upon being energized, bring these cathodes to an emissive condition. Transformers T11 and T14 are associated, respectively, with the grid circuits of valves V1 and V2 and are connected to apply biasing potentials to these grids which are 180° out of phase with the anode potentials, thereby normally biasing these valves to the non-conductive condition.

It is noted that the cathode of valve V3 is, under the normal conditions illustrated, at the potential of the positive conductor 20, whereas the grid of this valve is at a lower value determined by the connection 10 on the resistor r1. Consequently, this valve is normally biased to a non-conductive condition. A small amount of additional bias is afforded by transformer T3 in the grid circuit of valve V3, which applies a potential thereto which is 180° out of phase with the anode potential. Transformer T3, however, is utilized primarily to increase the accuracy of the cutoff point of valve V3, as described below, and preferably has a relatively low voltage. Thus, the primary bias on valve V3 is derived from the aforesaid potentiometer connections. It is noted that valve V4 is normally biased to a negative condition by the potential which normally appears across resistor r11. Resistor r11 is connected in parallel with condenser C5, one plate whereof is connected to the positive bus 20 and the other plate whereof is connected to the negative bus 22 through resistor r15.

Transformers T5 and T9 are connected in the plate circuits of valves V3 and V4, respectively, but since these valves are now in a non-conduc-

tive condition, the energization of transformers T5 and T9 is without immediate effect.

The energization of the direct current conductors 20 and 22 serves to initiate the action of the oscillator circuit comprising valve V6, and to cause transformer T17 to be energized at a predetermined point in each positive half cycle of the alternating current supply. More particularly, the oscillator condenser C2 is connected directly across the conductors 20 and 22 in parallel with the primary winding of transformer T17 and in series with resistor r6. The energization of conductors 20 and 22, consequently, enables the flow of charging current to condenser C2, causing the latter to apply a potential across transformer T17 and valve V6. The grid of valve V6 is brought to a positive value once in each positive half cycle and is brought to a negative value once in each negative half cycle, under the influence of the remaining aforesaid transformer T10, the secondary winding whereof is coupled to the grid of valve V6 through a conventional phase shifting arrangement comprising resistors r7, r8, r9, r10 and condenser C3. It will be understood that this phase shifting arrangement may be adjusted to provide any desired phase relation between the potential applied to the grid of valve V6 and the potential applied to transformer T10 and to the main rectifiers R1 and R2. It is preferred to adjust the phase shifting circuits so that the grid of valve V6 is brought to a critically positive value at a point corresponding to the power factor angle of the welding load circuit. At such point in the positive half cycle, following the energization of conductors 20 and 22, accordingly, valve V6 is rendered conductive, enabling condenser C2 to discharge through valve V6 and supply a surge current to transformer T17, which surge current persists during only a very small portion of the positive half cycle. When the potential of condenser C2 falls to zero or substantially zero, the arc in valve V6 is extinguished. Condenser C2 continues to receive charging current during the balance of the positive half cycle in question, during which the grid of valve V6 is positive, and, as a consequence, a succession of minor discharges may be passed through valve V6 during such balance. These discharges are, however, so small that the resultant energizations of transformer T17 are negligible. At the beginning of the succeeding negative half cycle of grid voltage, the grid of valve V6 becomes negative and, following the last such minor discharge during the positive half cycle, valve V6 becomes non-conductive and remains so during the full negative half cycle of grid voltage. During this non-conductive period, condenser C2 recharges, and the constants of the charging circuit are such that condenser C2 is enabled to reach a desirably high charge before the grid of valve V6 again becomes critically positive. With this relation, it will be understood that at the critical point in each positive half cycle, condenser C2 discharges and operatively energizes transformer T17, which energization is of an extremely sharply peaked character, as is indicated by the curve *a* in Fig. 2. It will be recognized that an oscillator circuit of the present type can be adjusted so that the voltage output of transformer T17 is high enough to fire valve V5 for only an exceedingly short period of time, of the order, for example, of two to three electrical degrees. It has heretofore been proposed to supply the grid of starting valves in synchronous control systems with peaked impulses, but the refined character of the impulse produced

by an oscillator circuit is of very material importance and amounts to a decided improvement over conventional peaking arrangements. The positive impulse applied to the grid of valve V5, at a predetermined point in each positive half cycle of the source, as aforesaid, is normally without effect, since the plate circuit of the starting valve V5 is open at contact CR2a.

The energization of the line conductors L1 and L2, in addition to the preparatory operations mentioned above, also operates interlock relay CR1, which thereupon closes its contacts CR1a and CR1b in the firing circuits of the valves V1 and V2.

Assuming it is desired to effect a welding operation, and assuming, further, that the work has been properly located between the electrodes e, the start switch 26 may be closed. This action may be accomplished in any suitable manual or automatic manner. For example, assuming it is desired to correlate the starting of the system to the clamping of the work, the closure of the start switch 26 may be caused to occur automatically after the work has been clamped. More particularly, utilizing the circuits designated "sequence circuits" in the aforesaid copending application Serial No. 402,922, the start switch 26 may correspond to a normally open contact on the control relay R3 of the copending application.

Closure of the start switch 26 completes an obvious energizing circuit for the winding of a usual electromagnetically operated control relay CR2, which thereupon closes its contact CR2a and opens its contact CR2b. The opening of contact CR2b interrupts the normally complete discharge circuit for the timing condenser C1. Closure of contact CR2a completes a circuit across the principal electrodes of valve V5 as follows: From the potentiometer connection 12 through valve V5, contact CR2a, the network comprising condenser C1 and resistors r4 and r5, to the positive conductor 20. A branch of this circuit in parallel with resistor r4 extends from the terminal 16 through the grid cathode circuit of valve V3, resistor r2, transformer T3, connection 10, and lefthand portion of resistor r1 to conductor 20. Closure of these circuits (at contact CR2a) may occur at random, and at the next peaking point of transformer T17, valve V5 is rendered conductive. At this time, valve V5 brings the terminal 15 to substantially the potential of the terminal 12. Since condenser C1 is fully discharged, point 16 and, consequently, the cathode of valve V3 are also brought to substantially the potential of the point 12. Point 12 is negative with respect to the connection 10 and, therefore, the firing of valve V5 brings the grid of valve V3 to a potential which is considerably positive relative to the cathode and renders valve V3 conductive.

At the time valve V3 is rendered conductive (which action takes place, as aforesaid, at approximately the power factor angle of the load circuit), transformer T5 is effective to apply a conductive potential across the plate and cathode of valve V3. At the time in question, accordingly, valve V3 passes current and enables transformer T5 to energize transformers T15 and T16.

Upon being energized, transformer T15 immediately builds up a potential across resistor r13, which potential is approximately in phase with the anode potential applied to the firing valve V1. This potential, which considerably exceeds the bias potential of transformer T11, ren-

ders valve V1 conductive and causes a firing potential to be applied between the igniter electrode i and the cathode c of rectifier R1. Pursuant to this action, rectifier R1 becomes conductive and initiates a flow of load current to the welding transformer WT, it being understood, as aforesaid, that this flow is initiated, in the preferred practice of the invention, at a point not earlier than the power factor angle of the system.

The energization of transformer T16 during the aforesaid positive half cycle applies a potential between the grid and cathode of valve V4, which increases the normal negative bias on this valve, and which is, consequently, without immediate effect. Current flow through valve V3 persists for a time after the beginning of the succeeding negative half cycle of anode voltage of this valve, and during this time, the voltage across transformer T16 reverses. This reverse voltage of transformer T16 occurs at a time when the anode of valve V4 is positive, and serves to overcome the negative bias on valve V4 and render the same conductive. At this time, transformer T9, which is continuously energized, is enabled to pass current through valve V4 and energize transformer T18. Transformer T18, when energized, in turn, impresses a potential across resistor r14, which renders valve V2 conductive and enables this valve to fire the other main rectifier R2. The firing of rectifier R2 may be expected to take place at a time which is in advance of the power factor angle of the welding load circuit, since the power factor angle of such load is greater than the power factor angle of the control circuits. Since, however, main rectifier R1 remains conductive throughout the full positive half cycle of load current flow, rectifier R2 does not begin to pass current until the beginning of the negative half cycle of load current flow. Thus, rectifier R2 takes up the load at the power factor angle of the load circuit and conducts current to the welding transformer during the negative half cycle.

At the beginning of the next succeeding positive half cycle, transformer T5 again brings the plate of valve V3 to a positive value and passes current through this valve to again energize transformers T15 and T16. Transformer T15 functions, as before, to fire valve V1 which, in turn, fires rectifier R1. This action may be expected to occur at approximately the power factor angle of the load circuit so that the rectifier R1 will take up the load current when rectifier R2 ceases passing current, which action occurs at the conclusion of the negative half cycle of load current. Having taken up the load current at the beginning of the positive half cycle of load current, rectifier R1 remains conductive throughout the balance of such half cycle. The initial energization of transformer T16 is, as before, without effect, but the reversal of the voltage of this transformer at the end of the positive half cycle in question again renders valve V4 conductive, enabling transformer T9 to energize transformer T18. Transformer T18, when energized, again fires main rectifier R2. So long, therefore, as valve V3 remains conductive, rectifiers R1 and R2 continue to pass the respective positive and negative half cycles of the load current.

So long as contact CR2a (closure of which initiated the flow of welding current, as aforesaid) remains closed, two charging circuits are provided for condenser C1. One of these charg-

ing circuits is the previously traced circuit which includes the grid and cathode of valve V3. The other branch charging circuit, which passes a highly predominant portion of the charging current, includes resistor r4, one terminal of which is connected to junction 14 on the positive bus 20. Consequently, during the flow of welding current, the potential across condenser C1 progressively rises. During this charging, the potential of the junction 16 and, consequently, the potential of the cathode of valve V3, is lower than the potential of junction 14 by an amount equal to the voltage drop across the resistor r4. On the other hand, during this charging, the potential of the grid of valve V3 is below the potential of the point 14 by an amount equal to the drops across resistor r2 and across that much of resistor r1 which falls between the junctions 10 and 14, plus or minus the voltage of transformer T3. At a rate which is dependent primarily upon the relative adjustments of resistances r1, r2 and r4, therefore, the potential of the grid of valve V3 becomes less positive, or increasingly negative, relative to the cathode of this valve. At the expiration of the desired timing period, the grid of valve V3 becomes critically negative relative to the cathode thereof and cuts off valve V3. It will be understood that this cutoff point is made considerably more sharp by superimposing on the falling curve of grid potential, determined by the potentiometer connections, the small pulsating curve of grid bias afforded by transformer T3.

If the aforesaid cutoff condition is attained during a positive half cycle, but at a time therein after valve V3 has started to pass current, it has no effect, as will be understood, upon the flow of current through valve V3 during such positive half cycle. The attainment of this condition does, however, prevent the initiation of current flow through valve V3 at the beginning of the next succeeding positive half cycle. The blocking of valve V3 thus interrupts further firing of the main rectifiers R1 and R2. Also, in view of the consequential mode of operation of valve V4, rectifier R2 is always the last main rectifier to be fired. By varying the position of the junction 10 along the resistance r1, the charging interval of the condenser C1 can be varied between relatively wide limits of the order, for example, of from one full cycle of the source to several seconds.

At the conclusion of the flow of welding current, the system may be reset, in readiness for a new operation, by releasing the start switch 26 to the open position, which action de-energizes relay CR2 and causes it to open its contact CR2a and close its contact CR2b. The opening of contact CR2a serves only to interrupt the plate circuit of valve V5. The closure of contact CR2b completes a discharge circuit for condenser C1 through resistor r3, thus restoring this condenser to its original discharged condition. As soon as these reset operations have occurred, a new operation may be initiated by reclosing the start switch 26. It will be understood that in utilizing the present synchronous system with the sequence control circuits of the copending application, Serial No. 402,922, the re-opening of switch 26 occurs automatically as a result of the timing out of the control relay designated R3 in said copending application. This timing out also resets the other sequence control circuits and results in releasing the electrodes from the work. In such cases, it will be understood that the time

interval afforded by relay R3 of the copending application is set to very slightly exceed the time interval afforded by condenser C1, so that the period of welding current flow is determined by condenser C1. In certain cases, it is desirable to enable the cessation of flow of welding current to immediately reset the associated sequence circuits. In such cases the present synchronous control circuits may be utilized with the sequence control circuits shown in the copending Collom application, Serial No. 421,164. More particularly, switch 26 of the present disclosure may be operated by relay R3 of said copending application, Serial No. 421,164, or, alternatively, relay CR2 of the present application may be said to correspond to and perform the functions attributed to relay R3 of said copending application. With this associated control system, the cessation in flow of the welding current at the conclusion of the timing period automatically initiates the resetting of the various sequence circuits.

With the illustrated system, as aforesaid, the firing of the main rectifiers occurs at the power factor angle of the load circuit so that full or maximum heat is supplied to the welding transformer. It will be appreciated that, if desired, phase shifting apparatus may be introduced into the herein illustrated system in precisely the same manner that such phase shifting apparatus is introduced into the system disclosed in the aforesaid copending application, Serial No. 402,922. More particularly, in the present disclosure a jumper 50 is connected in the primary circuit of transformer T15 and a jumper 52 is connected into the primary circuit of transformer T18. If it is desired to introduce phase shifting apparatus, phase shifting valves, such as V7 and V8 of the copending application, Serial No. 402,922, may have their principal electrodes connected to the terminals which are joined by the just-mentioned jumpers. With this arrangement, the firing of valves V3 and V4 is not effective, during the corresponding positive and negative half cycles, to fire valves V1 and V2 until such times in such half cycles as the corresponding phase shift valves are rendered conductive. Current flow through the valve V3 is sustained from the time this valve is fired until the phase shift valve is fired through the circuit through transformer T16, which parallels the circuit for transformer T15. Similarly, current flow through valve V4 is sustained through resistor r12, which parallels transformer T18.

Although only a single specific embodiment of the invention has been described in detail, it will be appreciated that various further modifications in the form, number and arrangement of parts may be made without departing from the spirit and scope thereof.

What is claimed is:

1. In a timing control system for a normally non-conductive electric discharge apparatus for controlling the flow of current to an electrical load from an electrical source which supplies a succession of current pulses of one polarity, a translating means distinct from the load, a valve having principal electrodes and a control electrode, means coupling said translating means and said electrical source between the principal electrodes of said valve so that while said valve is conductive said translating means is operated during each said pulse to render the apparatus operable to conduct at least a portion of said pulse to the load, means for controlling the conductivity of said valve including an energy storage device

connected to receive charging current through a circuit which includes the control electrode and one of the principal electrodes of said valve, said device, on initial closure of said circuit, acting to render said valve conductive and, after being charged to a predetermined degree, acting to render said valve non-conductive, and control means including means operable synchronously with said source for effecting closure of said circuit.

2. In a timing control system for a normally non-conductive electric discharge apparatus for controlling the flow of current to an electrical load from an electrical source which supplies a succession of current pulses of one polarity, a translating means distinct from the load, a valve having principal electrodes and a control electrode, means coupling said translating means and said electrical source between the principal electrodes of said valve so that while said valve is conductive said translating means is operated during each said pulse to render the apparatus operable to conduct at least a portion of said pulse to the load, means for controlling the conductivity of said valve including an energy storage device connected to receive charging current through a circuit which includes the control electrode and one of the principal electrodes of said valve, said device, on initial closure of said circuit, acting to render said valve conductive and, after being charged to a predetermined degree, acting to render said valve non-conductive, and control means including an oscillatory network having a peaked output for effecting closure of said circuit.

3. In a control system for controlling the flow of current between a load circuit and a source of alternating current, the combination of a pair of rectifiers interposed between said source and said load circuit and disposed to pass half cycles of respectively opposite polarity of said source, a synchronizing network for said rectifiers comprising first and second control valves, said network further comprising means for transmitting an impulse of current from said source through one of said control valves during a said half cycle of one polarity, means rendering the corresponding rectifier operably responsive to said impulse, means responsive to said impulse for storing a portion thereof and for consequently enabling said source to transmit a second impulse through said second control valve during the succeeding half cycle of opposite polarity, means rendering the said other rectifier operably responsive to said second impulse, said one of said control valves having a control electrode and principal electrodes, an energy storage device, circuit means including two branch circuits for coupling said energy storage device to a source of charging current, one of said branch circuits including the grid and cathode of said one control valve, said device acting upon initial closure of said circuit means to render said one control valve conductive and acting, when charged to a predetermined degree, to render said one control valve nonconductive.

4. In a control system for controlling the flow of current between a load circuit and a source of alternating current, the combination of a pair of rectifiers interposed between said source and said load circuit and disposed to pass half cycles of respectively opposite polarity of said source, a synchronizing network for said rectifiers comprising first and second control valves, said network further comprising means for transmitting

an impulse of current from said source through one of said control valves during a said half cycle of one polarity, means rendering the corresponding rectifier operably responsive to said impulse, means responsive to said impulse for storing a portion thereof and for consequently enabling said source to transmit a second impulse through said second control valve during the succeeding half cycle of opposite polarity, means rendering the said other rectifier operably responsive to said second impulse, said one of said control valves having a control electrode and principal electrodes, an energy storage device, circuit means including two branch circuits for coupling said energy storage device to a source of charging current, one of said branch circuits including the grid and cathode of said one control valve, said device acting upon initial closure of said circuit means to render said one control valve conductive and acting, when charged to a predetermined degree, to render said one control valve nonconductive, and control means including an oscillatory network having a peaked output for effecting closure of said circuit means.

5. In a timing control system for a plurality of electric discharge devices each having principal electrodes and a control element, a plurality of valves, means operated when said valves are rendered conducting for respectively applying an operating potential between the corresponding control element and one of the corresponding principal electrodes, a control member movable between first and second positions, means responsive to movement of said control member to said first position for rendering one of said valves conducting, means responsive to the conducting condition of said one valve for rendering another of said valves conducting, said last-mentioned means being operably independent of the operation of the said device corresponding to said one valve, and blocking means the effect of which is released when said control member is moved to said second position, said blocking means preventing the re-operation of said one valve until so released.

6. In a timing control system for association with a source of pulsating current, a valve having principal electrodes and a control electrode, a translating means, means distinct from said translating means and controlled in accordance with the conductive condition of said valve to energize said translating means each pulsation of said source during a conductive condition of said valve, means for controlling the conductivity of said valve including an energy storage device connected to receive charging current through a circuit which is coupled to said valve in such relation that the potential of said device determines the conductive condition of said valve, said device, on initial closure of said circuit, causing said valve to assume one conductive condition and, after being charged to a predetermined degree, causing said valve to assume another conductive condition, and means for controlling said circuit including first means operable at random relative to the pulsations of said source and a second means operable in predetermined timed relation to said pulsations, said second means including an electric control valve and means having a peaked output for controlling its conductivity.

7. In a control system for controlling the flow of current between a load circuit and a source of alternating current, the combination of a pair of rectifiers interposed between said source and said

load circuit and disposed to pass half cycles of respectively opposite polarity of said source, a synchronizing network for said rectifiers comprising first and second control valves, said network further comprising means for transmitting an impulse of current from said source through one of said control valves during a said half cycle of one polarity, means rendering the corresponding rectifier operably responsive to said impulse, means responsive to said impulse for storing a portion thereof and for consequently enabling said source to transmit a second impulse through said second control valve during the succeeding half cycle of opposite polarity, means rendering the said other rectifier operably responsive to said second impulse, and means for controlling the conductivity of said one control valve including an energy storage device connected to receive charging current through a circuit which is coupled to said one control valve in such relation that the potential of said device determines the conductivity of said one valve, said device, on initial closure of said circuit, acting to render said valve conductive and, after being charged to a predetermined degree, acting to render said valve non-conductive, and control means including means operable in predetermined timed relation to said source for effecting closure of said circuit.

8. In a timing control system for a plurality of electric discharge devices each having principal electrodes and a control element, a plurality of valves, means operated when said valves are rendered conducting for respectively applying an operating potential between the corresponding control element and one of the corresponding principal electrodes, a control member movable between first and second positions, means responsive to movement of said control member to said first position for rendering one of said valves conducting, means responsive to the conducting condition of said one valve for rendering another of said valves conducting, said last-mentioned means being operably independent of the operation of the said device corresponding to said one valve, and energy storage means operable to render said one valve non-conductive and to hold said one valve non-conductive until said member is moved to said second position.

9. In a timing control system for a plurality of electric discharge devices each having principal electrodes and a control element, a plurality of valves, means operated when said valves are rendered conducting for respectively applying an operating potential between the corresponding

control element and one of the corresponding principal electrodes, a control member movable between first and second positions, means responsive to movement of said control member to said first position for rendering one of said valves conducting, means responsive to the conducting condition of said one valve for rendering another of said valves conducting, said last-mentioned means being operably independent of the operation of the said device corresponding to said one valve, and energy storage means operable when said control member is in said one position for determining the time period during which said one valve is maintained conductive and operable to maintain said one valve non-conductive until said control member is moved to said second position.

10. In a timing control system for a plurality of electric discharge devices each having principal electrodes and a control element, a plurality of valves, means operated when said valves are rendered conducting for respectively applying an operating potential between the corresponding control element and one of the corresponding principal electrodes, a control member movable between first and second positions, means responsive to movement of said control member to said first position for rendering one of said valves conducting, means responsive to the conducting condition of said one valve for rendering another of said valves conducting, said last-mentioned means being operably independent of the operation of the said device corresponding to said one valve, and a condenser operable to determine the time period during which said one valve is maintained conductive and operable to maintain said one valve non-conductive until said control member is moved to said second position.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,061,011	Vingerhoets	Nov. 17, 1936
2,126,398	Knowles	Aug. 9, 1938
2,132,264	King	Oct. 4, 1938
2,190,775	Edwards	Feb. 20, 1940
2,195,996	Palmer	Apr. 2, 1940
2,263,307	Lord	Nov. 18, 1941
2,270,799	Gulliksen	Jan. 20, 1942
2,016,147	La Pierre et al.	Oct. 1, 1935