Aug. 16, 1938. C. G. SUITS 2,127,439

ELECTRIC VALVE CIRCUITS

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Fig. 1.

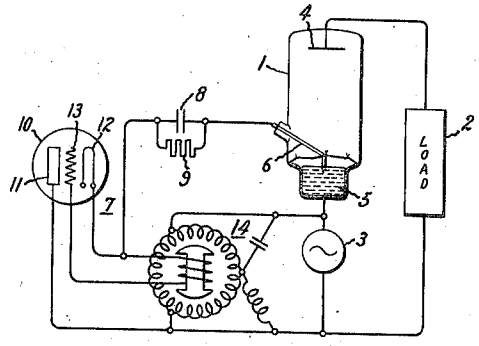
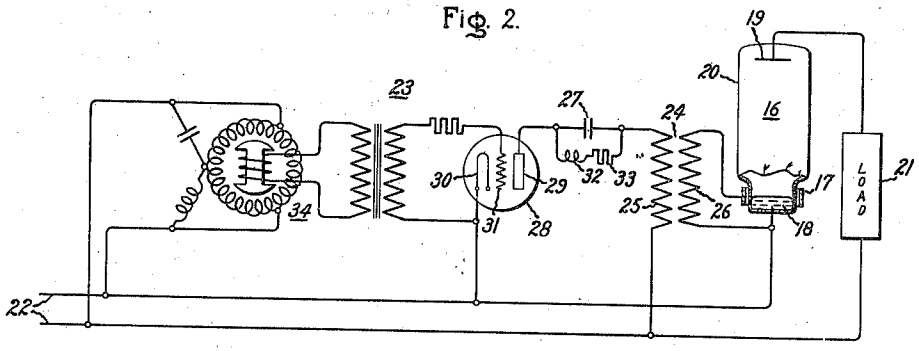


Fig. 2.



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ELECTRIC VALVE CIRCUITS

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16 Claims. (Cl. 175—363)

My invention relates to electric valve circuits, and more particularly to excitation circuits for electric valves of the vapor electric discharge type.

In the use of valves of the vapor electric discharge type in electric translating circuits, it is desirable to have an excitation circuit which will provide a periodic control potential, the positive portions of the cycle of which provide a relatively steep wave front. It is also desirable to provide an excitation circuit which is simple in arrangement and which is reliable in operation.

The electric valve devices utilized in the apparatus of the type to which my invention particularly applies, in general, comprise a plurality of principal electrodes between which an electric discharge is to pass. The electric discharge may be initiated by impressing a large potential between these electrodes. However, in the illustration of the embodiments of my invention described hereinafter, the electric valves are rendered conductive by impressing suitable potentials upon a control electrode associated with one of the principal electrodes. In a particular type of electric valves that are used in one of the illustrated embodiments of my invention, at least one of the principal electrodes is a conductive liquid or suitable solid in which the associated control electrode is immersed. This type of electrode, which is immersed in one of the principal electrodes, may be termed an immersion-igniter, since it effects ignition of the electric valve when a suitable current is passed through the immersion igniter to the associated principal electrode. More particularly, a suitable valve utilizing the immersion-igniter is one in which the associated principal electrode is mercury and the immersion-igniter is of a material of relatively high specific electrical resistivity as compared to the resistivity of mercury. In such an arrangement, the mercury pool will be the cathode of the rectifying valve. To initiate the discharge and render the electric valve conductive, an electric current is conducted through the immersion-igniter into the mercury, the polarity of the immersion-igniter being positive relative to the mercury.

It has been found heretofore that in order to provide suitable ignition of these valves with the desirable regularity and certainty, relatively large currents must be transmitted through the immersion-igniter to the mercury.

Another type of electric valve to which my invention may be applied is one in which the control or starting member is of the band type associated with one of the principal electrodes. This member may be an inner or outer body acting electrostatically upon the associated electrode. In this type of valve, it is preferable, where one of the electrodes is a liquid such as mercury, that a portion of the starting band extend above the level of the liquid. To initiate the electric discharge in this type of electric valve, it has been found necessary to furnish a relatively large voltage to the starting member.

There has been evidenced a very definite need for simple and reliable apparatus to excite or ignite electric valves of the above discussed types, at predetermined points in the half cycle of positive potential applied between the principal electrodes. Due to the complex nature of the phenomena incident to electric valves utilizing the immersion-igniter method or principle of ignition or starting, it has been apparent that excitation systems for rendering these valves conductive must not only be positive and reliable in operation, but must also be readily adaptable to furnish an electrical impulse to excite the valve at certain predetermined recurring intervals.

It is an object of my invention to provide for electric valves an improved excitation circuit which will have the above-mentioned desirable characteristics and which will be simple and reliable in operation.

It is another object of my invention to provide an improved excitation system for electric valves of the vapor electric discharge type which will provide an electrical impulse to the control member to render the electric valve conductive at a predetermined point of a positive half cycle of the anode-cathode potential.

It is a further object of my invention to provide an improved excitation system for electric valves of the vapor electric discharge type which will render the electric vapor conductive at a predetermined point in the positive half cycle of the anode-cathode potential and which may be effective to render the valve conductive at only predetermined recurring intervals.

For a better understanding of my invention together with other and further objects thereof, reference is had to the following description taken in conjunction with the accompanying drawing, and its scope will be pointed out in the appended claims.

In accordance with the illustrated embodiment of my invention, I provide an improved excitation circuit for electric valves which makes it possible to supply electrical impulses of suitable magnitude and wave form to obtain satisfactory

excitation of electric valves and which is readily adaptable to render the valves conductive at particular recurring intervals. The periodic excitation comprises means for impressing upon the control member of the electric valves a suitable excitation impulse and means for storing energy within the circuit. The energy stored within the circuit during the interval of excitation is subsequently dissipated in a discharge circuit, not including the control member, which may or may not be oscillatory. Re-energization of the control member may be delayed for a predetermined interval by choosing suitable values for the physical constants of the excitation circuit. Although not limited thereto, my excitation circuit is particularly adaptable to electric valves of the type utilizing an immersion-igniter or a starting band.

In the drawing Fig. 1 illustrates diagrammatically an embodiment of my invention as applied to an electric valve of the type having an immersion-igniter; and Fig. 2 shows diagrammatically an embodiment of my invention as applied to an electric valve having a starting or control member of the starting band type.

Referring now to Fig. 1 of the drawing, there is shown diagrammatically an arrangement for rendering an electric valve 1 conductive at predetermined points in the positive half cycle to supply a unidirectional current to a load circuit 2 from an alternating current source 3. The electric valve 1 is provided with an anode 4 and a cathode 5 which may be a pool of mercury, and a starting or control electrode 6 which is of the immersion-igniter type consisting of a rod of material of relatively high specific electrical resistivity having an extremity thereof extending into and immersed in the mercury pool 5. Although not specifically limited thereto, the immersion-igniter may be of a material such as boron-carbide, silicon-carbide, graphite or other suitable material. Some of the materials which may be used as immersion-igniters in addition to possessing relatively high specific resistivities have a non-linear volt-ampere characteristic.

An excitation circuit 7 is provided to energize the immersion-igniter 6 from the source of alternating current 3. The excitation circuit 7 comprises a capacitance 8 connected in parallel with a resistance 9 and an electric valve 10 having an anode 11, a cathode 12 and a control grid 13. It will be understood by those skilled in the art that the electric valve 10 although hereinafter described as being of the vapor electric discharge type may also be of the high vacuum type. The electric valve 10 is provided to supply impulses of positive current to the immersion-igniter 6 through the capacitance 8 at a predetermined point during the positive half cycle of the alternating potential supplied by the source 3. A conventional phase shifting arrangement 14 is provided to control the phase of the potential impressed upon the control grid 13 of electric valve 10 relative to the potential impressed upon anode 11.

The operation of the preferred embodiment of my invention as diagrammatically illustrated in Fig. 1 may be best explained by considering the circuit when the alternating current source 3 is supplying a potential which renders the anode 4 of electric valve 1 positive relative to the cathode 5. During this positive half cycle it will be apparent that the potential impressed between anode 11 and cathode 12 of electric valve 10 will be in a direction tending to render electric valve 10 conductive and to transmit a positive electric impulse from the alternating current source 3 through electric valve 10, capacitance 8, through immersion-igniter 6, to the cathode 5. It will be evident that if the potential of control electrode 13 of electric valve 10 is positive relative to that of the cathode 12 during this positive half cycle, the electric valve 10 will conduct current to charge the capacitance 8 in such a manner that a positive current flows from the immersion-igniter 6 to the cathode 5. If the potential of the control electrode 13 is retarded relative to the potential impressed between the anode 11 and the cathode 12 so that the electric valve 10 becomes conductive at a later point during the positive half cycle, that is, at a point where the anode-cathode potential is somewhere near the maximum value of the wave, a potential of relatively large value and of substantially perpendicular wave front will be impressed upon the capacitance 8, resulting in the transmission of a relatively large transient current through the immersion-igniter 6 to the cathode 5.

Although the theory explaining the operation of an electric valve having an immersion-igniter is somewhat conjectural, it is quite generally understood that the electric valve 1 will be ignited or rendered conductive by the relatively large current passing through the immersion-igniter. It will be further apparent that the alternating current source 3 will supply an impulse of unidirectional current to the load circuit 2 during each half cycle of positive anode-cathode potential.

From the above description, it will be apparent that if electric valve 10 is rendered conductive during the positive half cycle the capacitance 8 will be charged at the end of that positive half cycle. During the following negative half cycle the capacitance 8 will discharge through the parallel-connected resistance 9, since the electric valve 10 will be non-conductive inasmuch as the potential of the cathode 12 is positive relative to the anode 11. Since the time-constant of the parallel-connected capacitance 8 and resistance 9 is relatively small, the energy stored within the capacitance 8 during the positive half cycle may be quite readily dissipated in resistance 9 during the following negative half cycle, thereby making it possible for the electric valve 10 during the following positive half cycle to repeat the cycle of operations previously described. During each positive half cycle of the potential supplied by alternating current source 3, energy will be stored in the capacitance 8 during which interval the immersion-igniter 6 will be energized by a relatively large transient current of short duration, and during the following negative half cycle the energy stored in the capacitance 8 will be dissipated in the resistance 9 to restore the excitation circuit to a condition which will enable the valve 10 to furnish another impulse of relatively large current of short duration to the immersion-igniter during the following positive half cycle. It is desirable to use a resistance 9 of such a value that the time-constant of a parallel circuit comprising the capacitance 8 and the resistance 9 is relatively small and the period of discharge of the condenser is substantially less than one-half the period of the potential of the alternating current source 3. On the other hand, if the value of resistance 9 is made quite large so that the time-constant of the parallel circuit comprising the capacitance 8 and resistance 9 is relatively large and the period of discharge of capacitance 8 is

substantially greater than the period of the potential of alternating current source 3, it is to be noted that the voltage of the capacitance 8 may be maintained at a value to prevent the transfer of appreciable current to the immersion-igniter control member 6, thereby delaying the reenergization of control member 6 for a predeterminal interval of time. The capacitance 8 serves to control the ignition of electric discharges within electric valve 1 and also serves to control the interval of time between consecutive electric discharges therein. The interval of time may be controlled by the proper choice of values for capacitance 8 and resistance 9.

Referring now to Fig. 2 of the drawing in which there is represented diagrammatically an embodiment of my invention as applied to an electric valve 16 of the type utilizing a control member of the starting band type, having a starting band 17, a principal electrode 18 of mercury forming the cathode, an anode 19 and an envelope 20. Preferably, the starting band 17 is arranged exterior to the concentric with the envelope and may extend above the surface of the mercury pool cathode. Unidirectional current is supplied to a load 21 from a source of alternating current 22 through the electric valve 16.

An excitation circuit 23 is provided to supply a relatively high transient voltage to the starting member 17 from the alternating current source 22. Relatively large transient potentials are applied to the control member 17 through a transformer 24 having a primary winding 25 and a secondary winding 26, a capacitance 27 and an electric valve 28 having an anode 29, a cathode 30 and a control electrode 31. Although electric valve 28 is hereinafter described as being of the vapor electric type, it will be readily understood by those skilled in the art that this valve may be of the high vacuum type. A discharge path comprising a series-connected inductance 32 and a resistance 33 connected in parallel with the capacitance 27 is provided through which the capacitance is allowed to discharge. The control electrode 17 is connected to be energized from the alternating current source 22 through the excitation circuit 23. The excitation circuit 23 comprises the electric valve 28, an oscillatory circuit including the capacitance 27, the inductance 32 and the resistance 33, and the transformer 24. A conventional phase shifting arrangement 34 is provided to render electric valve 28 conductive at any desired positive potential of the alternating current source 22.

The operation of the embodiment of my invention shown in Fig. 2 may be best understood by first considering the arrangement during a positive half cycle of alternating potential when the source of alternating current renders the anode 19 of electric valve 16 positive relative to the cathode 18. During the positive half cycle, a potential which is positive relative to cathode 30 of electric valve 28 will be impressed upon anode 29. If the potential impressed on control electrode 31 of electric valve 28 is positive relative to the cathode during this positive half cycle but lags in phase the potential impressed between anode 29 and cathode 31 a large positive transient voltage will be transmitted to the control electrode 17, which will render electric valve 16 conductive to supply a pulse of unidirectional current to the load 21. During this part of the cycle of operation, the capacitance 27 will be charged, and during the following negative half cycle the capacitance 27 will discharge through the discharge circuit comprising inductance 32 and resistance 33. It will be understood that if the damping coefficient of the inductance and resistance discharge circuit is relatively large, the energy stored in the capacitance during the positive half cycle may be dissipated during the following negative half cycle, thereby occasioning a reduction in the counter-voltage of the capacitance to permit the above-described cycle of operation to be repeated. However, the value of the inductance 32 may be chosen so that the damping coefficient of the discharge circuit is relatively small to prevent the capacitance from discharging at a high rate. Under these conditions when the damping coefficient of the discharge circuit is small the counter-voltage of the capacitance 27 will decrease at a comparatively low rate during the negative half cycle. During the following positive half cycle the counter-voltage of the capacitance 27 will be sufficiently large to prevent re-energization of control member 17.

During a positive half cycle of potential a relatively large positive impulse of voltage will be supplied to the control member 17. As explained above, during this interval the capacitance 27 will be charged. To restore the excitation circuit to a condition of equilibrium, the capacitance 27 is permitted to discharge through a parallel circuit comprising the series-connected inductance 32 and resistance 33. It will be apparent to those skilled in the art that this parallel circuit will oscillate at its natural frequency. If the constants of this parallel circuit are chosen so that the natural resonance frequency is equal to the frequency of the alternating current source 22, the counter-electromotive force which this parallel circuit impresses upon the anode 29 of electric valve 28 will be substantially 180 electrical degrees out of phase with and of equal magnitude to the potential impressed between anode 29 and cathode 30 of electric valve 28 from the alternating current source 22. The difference between these two voltages, that is, the difference between the voltage impressed between the anode 29 and the cathode 30 and the counter-voltage of the capacitance 27, determines the point at which re-energization of the control member 17 may occur. If the potential of control electrode 31 of electric valve 28 is of the proper polarity relative to the cathode 30, electric valve 28 will become conductive when this difference of voltage attains a predetermined minimum positive value depending upon the characteristics of the particular electric valve employed. Under these conditions, if the damping coefficient of the parallel circuit comprising the capacitance 27 and the series-connected inductance 32 and resistance 33 is sufficiently small, the time of re-energization of the control member 17 may be delayed for many cycles depending upon the rate at which the counter-voltage of the condenser decreases. By a suitable choice of the values of the resistance, inductance and capacitance of this circuit and by controlling the magnitude of the voltage impressed upon this parallel circuit and the duration of such voltage, it will be understood that it is possible to delay for a predetermined period the time of re-energization of the control member 17. Although it is desirable to choose values of resistance, inductance and capacitance so that the parallel branch has a natural resonance frequency equal to the frequency of the alternating current source 22, it is not essential that such a condition exist. However, if the natural reso-

nance frequency of this parallel branch is not equal to the frequency of the alternating current source **22**, the period during which re-energization of the starting member **22** may be delayed will be considerably shortened.

It will be well understood by those skilled in the art that I may use any conventional phase shifting arrangement, such as the rotary phase shifting device **34**, to vary the phase of the potential impressed upon the control electrode **31** relative to the potential impressed between anode **29** and cathode **30** of electric valve **28**. By this means I may control the magnitude of the voltage impressed upon the parallel circuit, as well as the time of application of such voltage.

The illustrated embodiments of my invention have been shown as applied to electric valves of the vapor electric discharge type having control members of the immersion-igniter type and the starting-band type, but it will readily occur to those skilled in the art that my invention in its broader aspects may be applied to electric discharge devices generally.

While I have shown and particularly described certain embodiments of my invention and certain methods of operation embraced therein for the purpose of explaining its principle and showing its application, it will be obvious to those skilled in the art that many modifications are possible without departing from my invention in its broader aspects and I aim, in the appended claims, to cover all such modifications and variations 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 electric valve comprising at least two principal electrodes and a control member associated with one of said principal electrodes for rendering said electric valve conductive, a source of potential, a capacitance connected in series relation with said control member and said source, means comprising an electric valve for transmitting a relatively large transient electrical impulse from said source through said control member and said capacitance to render conductive said first mentioned electric valve, and a discharge circuit connected in parallel with said capacitance.

2. In combination, an electric valve comprising at least two principal electrodes and a control member of the immersion-igniter type associated with one of said principal electrodes for rendering said electric valve conductive, means comprising a source of current and a serially-connected electric valve and a capacitance for supplying a relatively large current of short duration from said source to said control member and a discharge circuit connected in parallel with said capacitance.

3. In combination, an electric valve comprising at least two principal electrodes and a control member associated with one of said principal electrodes for rendering said electric valve conductive, means comprising a source of alternating current, a serially-connected capacitance and an electric valve for transmitting a relatively large transient electrical impulse from said source through said control member, a discharge circuit connected in parallel with said capacitance, and means for rendering said second-mentioned electric valve conductive at a predetermined potential of said alternating current source.

4. In combination, an electric valve comprising at least two principal electrodes, a control member of the starting-band type associated with one of said principal electrodes for rendering said electric valve conductive, means comprising a serially-connected electric valve, a source of alternating current and a capacitance for transmitting a relatively large voltage of short duration from said source through said control member, a parallel discharge circuit for said capacitance, and means for rendering said second-mentioned electric valve conductive at a predetermined potential of said alternating current source.

5. In combination, an electric valve comprising at least two principal electrodes and a control member associated with one of said principal electrodes for rendering said electric valve conductive, a source of alternating current for applying an alternating potential between said principal electrodes, and means for energizing said control member comprising an electric circuit including a capacitance connected in parallel with a series-connected inductance and resistance and an electric valve for impressing a relatively high voltage upon said control member through said electric circuit.

6. In combination, an electric valve comprising at least two principal electrodes and a control member associated with one of said principal electrodes for rendering said electric valve conductive, a source of alternating current for applying an alternating potential between said principal electrodes, means for energizing said control member comprising an electric circuit including a capacitance connected in parallel with a discharge circuit and an electric valve for furnishing a relatively large current of short duration through said control member and said capacitance, and means for rendering said second-mentioned electric valve conductive at a predetermined value of the alternating potential of said alternating current source.

7. In combination, an electric valve comprising at least two principal electrodes and a control member associated with one of said principal electrodes for rendering said electric valve conductive, and means for energizing said control member comprising a source of alternating current, a parallel-connected capacitance and resistance and an electric valve in series relation with said source and said parallel-connected capacitance and resistance for transmitting a relatively large current through said control member and said capacitance from said source, said parallel-connected circuit having a period of discharge substantially less than one-half the period of the alternating potential of said alternating current source.

8. In combination, an electric valve comprising at least two principal electrodes and a control member associated with one of said principal electrodes for rendering said electric valve conductive, an alternating current source for impressing alternating potentials between said principal electrodes of said electric valve, and means for energizing said control member comprising an electric circuit including a capacitance connected in parallel with a discharge circuit and an electric valve for supplying a relatively large transient electrical impulse to said control member through said capacitance, said capacitance and said discharge circuit being oscillatory to permit energization of said control member at only predetermined recurring intervals.

9. In combination, an electric valve compris-

ing at least two principal electrodes and a control member associated with one of said principal electrodes for rendering said electric valve conductive, and an electric circuit for energizing said control member comprising a source of potential, a capacitance through which said control member is energized, an inductive discharge path for said capacitance, and means responsive to the difference between the voltage of said source and the counter-voltage of said capacitance and said discharge path to effect energization of said control member.

10. In combination, an electric valve comprising at least two principal electrodes and a control member associated with one of said principal electrodes for rendering said electric valve conductive, an alternating current source for impressing an alternating potential between said principal electrodes of said electric valve, and means for energizing said control member comprising an electric circuit having a capacitance connected in parallel with a series-connected inductance and resistance and an electric valve for supplying a relatively large current to said control member through said capacitance, said parallel circuit being oscillatory to permit energization of said control member at only predetermined recurring intervals.

11. In combination, an electric valve comprising two principal electrodes and a control member associated with one of said principal electrodes for rendering said electric valve conductive, an alternating current source for impressing an alternating potential between said principal electrodes of said electric valve, means for energizing said control member at a predetermined time during a positive half cycle of alternating potential comprising an electric circuit having a capacitance and an electric valve for transmitting a relatively large current through said control member and said capacitance, and a discharge circuit comprising a series-connected inductance and resistance connected in parallel with said capacitance, said discharge circuit and said capacitance being oscillatory and having a predetermined damping coefficient to permit oscillatory discharge of said capacitance during a predetermined number of following half cycles.

12. In combination, an electric valve comprising at least two principal electrodes and a control member associated with one of said principal electrodes for rendering said electric valve conductive, an alternating current source for impressing an alternating potential between said principal electrodes of said electric valve, means for energizing said control member at a predetermined time during a positive half cycle of alternating potential comprising an electric circuit having a capacitance and an electric valve for transmitting a relatively large current through said control member and said capacitance, and a discharge circuit comprising a series-connected inductance and resistance connected in parallel with said capacitance, said discharge circuit and said capacitance having a natural resonance frequency equal to the frequency of said alternating current source and having a predetermined damping coefficient to permit oscillatory discharge of said condenser and preventing re-energization of said control electrode during a predetermined number of following half cycles.

13. In combination, an electric valve comprising at least two principal electrodes, a control electrode of the immersion-igniter type associated with one of said principal electrodes for rendering said electric valve conductive, a load circuit energized through said electric valve, a source of alternating current for applying an alternating potential between said principal electrodes, and means comprising in series relation an electric valve and a capacitance and a resistance connected in parallel with said capacitance for transmitting a relatively large current of short duration through said control electrode at a predetermined time in the cycle of said alternating potential.

14. In combination, an electric valve including at least two principal electrodes and a control electrode of the immersion-igniter type comprising a material having a positive non-linear volt-ampere characteristic, and an excitation circuit for energizing said control electrode comprising a source of electric current, a capacitance, means for impressing a relatively large transient voltage on said control electrode through said capacitance from said source to render said electric valve conductive and a discharge circuit connected in parallel with said capacitance.

15. In combination, an electric valve including at least two principal electrodes and a control electrode of the immersion-igniter type comprising a material having a positive non-linear volt-ampere characteristic, and an excitation circuit for energizing said control electrode comprising a source of electric current, a capacitance, means including an electric valve for impressing a relatively large transient voltage on said control electrode through said capacitance from said source to render said first-mentioned electric valve conductive and a discharge circuit connected in parallel with said capacitance.

16. In combination, an alternating current supply circuit, a direct current load circuit, and a translating circuit for supplying unidirectional current to said load circuit from said alternating current circuit comprising an electric valve including at least two principal electrodes and a control electrode of the immersion-igniter type comprising a material having a positive non-linear volt-ampere characteristic, a capacitance, means for impressing a relatively large transient voltage on said control electrode through said capacitance to render said electric valve conductive and a discharge circuit connected in parallel with said capacitance.

CHAUNCEY G. SUITS.

DISCLAIMER

2,127,439.—*Chauncey G. Suits*, Schenectady, N. Y. ELECTRIC VALVE CIRCUITS. Patent dated August 16, 1938. Disclaimer filed April 11, 1942, by the assignee, *General Electric Company*.

Hereby enters this disclaimer to claims 1, 2, 3, 5, 6, 13, 14, 15, and 16 in said patent.

[*Official Gazette May 5, 1942.*]