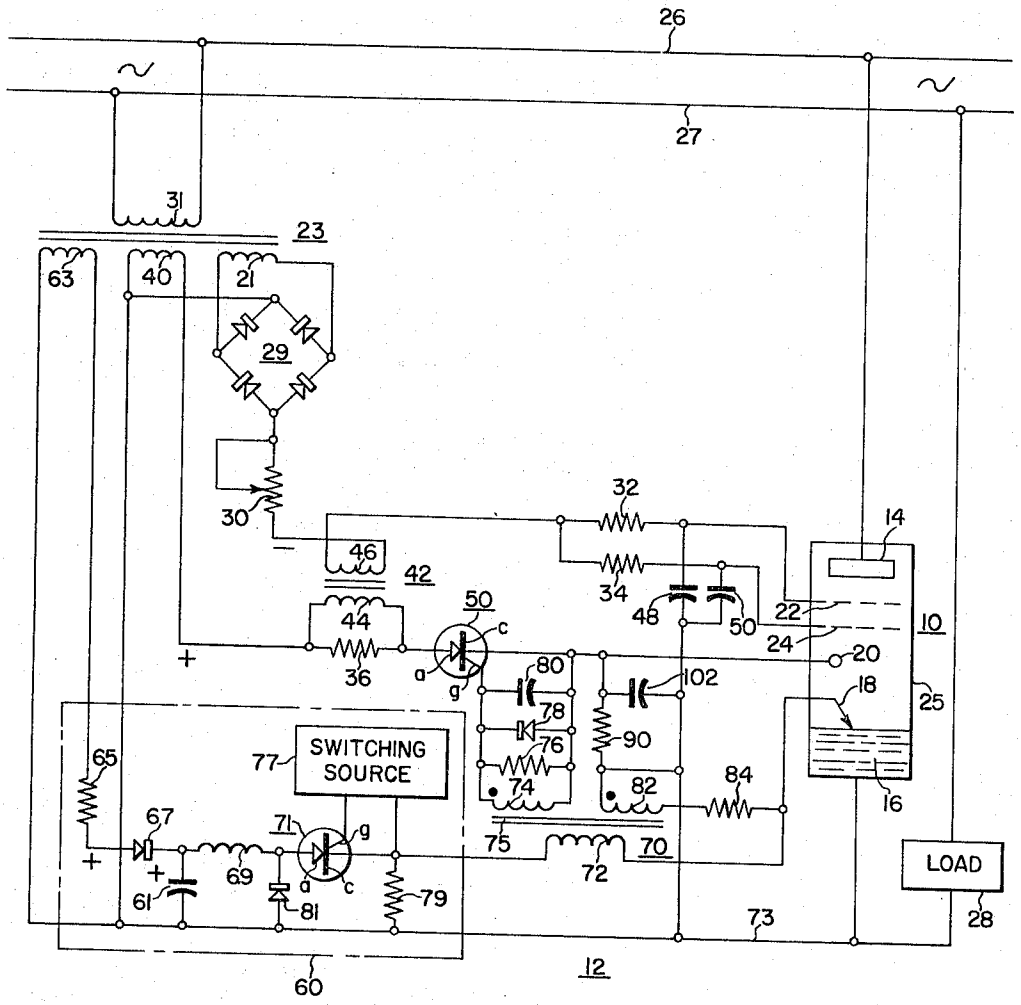
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PREIGNITION PREVENTION IN IGNITRONS BY DELAYED APPLICATION TO THE AUXILIARY ANODE

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WITNESSES

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PREIGNITION PREVENTION IN IGNITRONS BY DELAYED APPLICATION TO THE AUXILIARY ANODE

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This invention relates in general to electrical control circuits and more particularly to electrical control circuits for mercury-arc type rectifiers.

Mercury-arc type rectifier tubes, of the type having a single main anode, a pool-type cathode, and an ignitor to initiate a cathode spot or electron emission prior to each conducting period, commonly called ignitrons, have not been utilized on certain applications requiring a wide range of voltage control due to an excessive rate of preignition breakdowns. A preignition breakdown may be an arc from some element of the ignitron tube, such as grids, shields or auxiliary anode, to some other surface within the tube, such as the tube wall, prior to ignition of the cathode spot by the ignitor. Preignition breakdown, in addition to causing loss of control of the ignitron tube, also materially aids deterioration of the tube due to sputtering of the surface to which the breakdown arc occurs, causing the surface to vaporize and deposit the ingredients of the vapor on the tube elements.

Preignition breakdown causes further problems when utilizing control circuits in which the ignitron grid means are released or made positive by coupling a signal into the grid circuit from one of the other tube elements, such as an auxiliary anode, when said other tube element conducts. Thus, if the ignitron grids are released by a signal coupled into the grid circuit when the auxiliary anode conducts, conduction of the auxiliary anode prior to the ignition of the cathode spot would prematurely release the ignitron grids.

Accordingly, it is an object of this invention to provide a new and improved control circuit for mercury arc rectifiers.

Another object of this invention is to provide a new and improved control circuit for ignitron rectifiers which precludes release of the ignitron grids prior to initiation of the cathode spot or electron emission from the cathode.

A further object of this invention is to provide a new and improved control circuit for ignitron rectifiers which eliminates preignition of any of the elements of the ignitron.

Another object of this invention is to provide a new and improved control circuit for ignitron rectifiers in which the application of voltage to one element of the ignitron is dependent upon current flow through the ignitor plus the collapsing voltage characteristic of the ignitor circuit.

Briefly, the present invention accomplishes the above cited objects by providing control or switching means, such as a thyratron or silicon controlled rectifier, connected in series circuit relation with the element of the rectifier tube which is not to be energized until after establishment of a cathode spot on the pool cathode. The switching means receives its switching signal from current flow through the ignitor circuit, with an overriding signal responsive to the voltage characteristic of the ignitor circuit preventing application of the switching signals to the switching means until the ignitor has initiated a cathode spot. More specifically, when a current pulse is applied to the ignitor circuit, the voltage of the ignitor circuit increases until a cathode spot is initiated, at which time the voltage of the ignitor circuit collapses or is reduced to the voltage drop across the arc. The rising voltage characteristic of the ignitor circuit is utilized, in combination with saturable core means, to prevent the current flow through the ignitor circuit from producing a switching signal. When the ignitor establishes a cathode spot, the ignitor voltage collapses, and the ignitor current flow is then allowed to produce a signal which switches the switching means from its nonconducting state to a conducting state, which allows a potential to be applied to the series connected tube element. Current flow through the series connected tube element may then be used to release the grids or overcome the negative bias applied to the grids, thus allowing the tubes to conduct electrons from its pool cathode to the main anode.

Further objects and advantages of the invention will become apparent as the following description proceeds and features of novelty which characterize the invention will be pointed out in particularity in the claims annexed to and forming a part of this specification.

For a better understanding of the invention, reference may be had to the accompanying drawing in which the single figure is a schematic diagram illustrating a control circuit incorporating the teachings of this invention.

Referring now to the drawing, the single figure illustrates an ignition type mercury-arc rectifier **10** and an associated control circuit **12**, which incorporates the teachings of this invention. The ignitron **10**, as illustrates an ignitron type mercury-arc rectifier **10** and an ignitor **18**, auxiliary anode **20**, and grid means including grids **22** and **24**, all disposed within a casing **25**. A source of alternating potential, represented by conductors **26** and **27**, and a load circuit **28**, are shown connected in series circuit relation in the anode **14**- cathode **16** circuit of the ignitron **10**. The alternating current circuit **26** and **27** is illustrated for purposes of simplicity as being a single phase circuit. However, it is well known in the art that there are many other possible connections in which ignitrons may be used, and this invention is, in general, applicable to all of them.

In the operation of an ignitron, a cathode spot is initiated on the mercury pool cathode **16** by means of an ignitor **18**, at a predetermined time during the positive voltage half cycle. When a current pulse or signal is applied to the ignitor **18**, a high voltage gradient is established at the point where the ignitor **18** enters the pool cathode **16**, initiating electron emission and establishing a cathode spot. The cathode spot is usually established in 10 to 150 microseconds after the current pulse enters the pool cathode. Once the cathode spot is initiated, an auxiliary or holding anode such as auxiliary anode **20**, may be used to maintain the cathode spot after the ignitor current peak has subsided, for the remaining portion of the positive voltage half cycle. The auxiliary anode **20** will maintain the cathode spot for low values of anode current and when the voltage magnitude of the alternating supply potential from conductors **26** and **27** is less than the back voltage of the vapor arc.

When the cathode spot is initiated on cathode **16**, if the auxiliary anode **20** has a positive potential applied to it, an arc will be established from the auxiliary anode **20** to the cathode **16**, with electrons flowing from the cathode **16** to the auxiliary anode **20**.

The ignitron grids **22** and **24** keep the anode **14** from conducting prematurely, by setting up a negative potential around it which precludes electrons from the cathode **16** or other surfaces within the ignitron, from being attracted to the anode **14**. In order to initiate conduction of the ignitron **10**, the grids **22** and **24** must be made sufficiently positive to allow electrons from the cathode **16** to flow to the anode **14** upon initiation of the cathode spot. When the cathode spot is initiated, current will flow through the auxiliary anode circuit, and this current

flow may be used to develop a potential which will overcome the negative bias applied to the grids 22 and 24 and allow electrons from the cathode 16 to flow to the main anode 14.

More specifically, the negative bias or unidirectional potential, may be developed by first obtaining the proper magnitude of alternating potential through a secondary winding 21 of a control transformer 23, which has a primary winding 31 connected to alternating potential conductors 26 and 27. This alternating potential may then be rectified in a bridge rectifier 29, with the negative bias being applied through an adjustable resistor 30 to the grids 22 and 24, through limiting resistors 32 and 34, respectively. In order to overcome the negative bias applied to grids 22 and 24 at the proper time, a voltage responsive to current flow through the auxiliary anode 20 may be produced across resistor 36. Resistor 36 is connected in circuit relation with secondary winding 40 of control transformer 23, which provides an alternating potential of the desired magnitude having the instantaneous polarity shown in the figure. In order to reflect the potential produced across resistor 36 by current flow therethrough, a coupling transformer 42 having a winding 44 connected across resistor 36, and a winding 46 connected in series circuit relation with resistor 30 and grids 22 and 24, may be used. The potential produced in winding 46 of coupling transformer 42 overcomes the negative bias applied to grids 22 and 24, making the grids 22 and 24 sufficiently positive to allow conduction between the cathode 16 and anode 14. Capacitors 48 and 50 may be connected from the grids 22 and 24, respectively, to the cathode 16 in order to insure that the potential of the grids 22 and 24 follows the cathode potential during sudden changes.

As hereinbefore stated, an alternating potential from winding 40 of transformer 23 is applied to auxiliary anode 20. If the alternating potential is applied to the auxiliary anode 20 during the complete positive half cycle, however, serious problems may be encountered. In certain applications or conditions, the auxiliary anode 20 may establish an arc to some surface within the ignitron tube 10 prior to initiation of the cathode spot on the cathode 16. An arc from the auxiliary anode 20 to the casing or wall 25 of the ignitron 10, or other elements within the ignitron 10, causes sputtering and release of undesirable vapors which coat the anode 14 and other elements, causing deterioration of the ignitron tube 10. Further, if the grids 22 and 24 are released upon current flow in the auxiliary anode circuit, as illustrated in the figure, they will be released or made positive prior to the firing of the ignitron, causing precise control over conduction of the ignitron 10 to be lost.

In order to prevent preignition of the auxiliary anode 20, with the accompanying sputtering and pre-release of the grids 22 and 24, a control or switching means having two main electrodes and a control electrode, such as a thyratron or, as illustrated, a controlled rectifier 50, may be utilized. A controlled rectifier 50, such as a solid state, semiconductor silicon controlled rectifier, having an anode electrode *a*, a cathode electrode *c*, and gate or control electrode *g*, is connected between the auxiliary anode 20 and the alternating potential from winding 40 of transformer 23, with its cathode *c* being connected to auxiliary anode 20 and its anode *a* being connected to resistor 36. As is well known in the art, silicon controlled rectifiers have the characteristic of blocking current in their forward direction until a certain voltage magnitude is reached. This voltage magnitude may be sharply reduced by applying a positive current pulse to its gate electrode *g*. Thus, the controlled rectifier may be utilized as a switch, with the switch being normally open and a gate signal being applied to close it. When the alternating current applied to the controlled rectifier reaches zero or voltage reversal, the controlled rectifier will turn off and another gate signal is required during the next positive voltage half cycle to turn on, or close the switch again.

A firing current pulse for firing or initiating the cathode spot on cathode 16 may be applied to the ignitor 18 from firing means or firing circuit 60. Firing circuit 60 is described in detail in U.S. Patent 3,030,550, issued Apr. 17, 1962 to G. Smeltzer and assigned to the same assignee as the present invention. However, it is obvious that any conventional firing circuit may be utilized. Firing circuit 60 comprises an energy device, illustrated in this instance as a capacitor 61. The capacitor 61 is charged to a predetermined value in the direction indicated by the plus sign in the figure through a charging circuit which may be a secondary winding 63 on control transformer 23. It can be seen from the figure that the secondary winding 63 of transformer 23 is connected in series circuit relation with a charging resistor 65, a diode 67, and the capacitor 61. The diode 67 is poled to charge the capacitor 61 to a predetermined value in the direction indicated by the plus mark in the figure. The capacitor 61 is connected through a pulse shaping inductance 69, a switching means 71, and the ignitor 18-cathode 16 of the ignitron 10. The cathode 16 of the ignitron 10 is connected back to capacitor 61 through conductor 73.

The semiconductor device 71 may be a controlled rectifier or any other three element semiconductor device which may be switched to a conducting state or a nonconducting state. The device 71 may be switched to its conducting state by some suitable switching source, which has been indicated generally at 77. It is to be understood that any suitable switching device such as a thyratron or other device may be substituted for the semiconductor switching device 71. The switching source 77 is a timed switching source which may be a conventional saw-tooth generator, and it serves to switch the device 71 "on" in timed relationship with respect to the phase of the alternating current of the supply energy at the proper time to cause the capacitor 61 to discharge through the ignitor 18-cathode 16 circuit of the ignitron 10. Switching sources such as 77 are conventional in the art. The device 71 is switched to its nonconducting state when the total current through the ignitor 18-cathode 16 becomes zero. A resistor 79 is connected across the ignitor 18-cathode 16 circuit. A semiconductor rectifier 81 is connected across the capacitor 61. It can be seen that the rectifier 81 is poled in the opposite direction to the charging rectifier 67.

In the operation of firing circuit 60, capacitor 61 is charged to a predetermined value from the alternating current supply lines 26 and 27 through the secondary winding 63 of transformer 23, the charging resistor 65, and the rectifier 67. During the charging of the capacitor 61 to the predetermined value, the switching device 71 is in its nonconducting or open state. After the capacitor 61 has been charged to its predetermined value in the positive direction as indicated by the plus mark in the figure, the switching source 77 applies a switching potential to the semiconductor device 71 to switch the device 71 to its conducting state. The capacitor 61 then discharges through the pulse shaping inductance 69, the switching device 71, the ignitor 18-cathode 16 circuit, and the conductor 73. Thus, the current builds up an opposite charge on capacitor 61. As soon as the total current in the igniter 18-cathode 16 circuit becomes zero, the capacitor 61 discharges through the diode 81 and the pulse shaping inductance 69 and starts building up a positive charge on the capacitor 61 in the direction necessary to provide the next pulse for firing the ignitron. Consequently, it is only necessary for the charging circuit to provide the additional energy which is lost in the ignitor 18-cathode 16 circuit to build up a positive charge on the capacitor 61 to the predetermined magnitude in the proper direction to provide the next pulse. The rectifier 67 is poled to prevent capacitor 61 from discharging back to the charging circuit before the ignitor 18-cathode 16 cir-

cuit fires. The resistor **79** which shunts the ignitor **18**-cathode **16** circuit and also shunts the capacitor **21** is a stabilizing resistor and enables capacitor **61** to discharge in case the ignitor **14** misfires.

A firing current pulse from firing circuit **60** may be utilized to develop a gate signal for controlled rectifier **50** which will turn controlled rectifier **50** on, or change it from its high impedance state to a very low impedance state. The positive current pulse necessary to gate the controlled rectifier **50** may be developed by utilizing a saturable current transformer **70**, having a winding **72** responsive to the flow of current in the ignitor circuit, and a winding **74**, having the instantaneous polarity shown, connected from the gate electrode *g* to the cathode electrode *c* of controlled rectifier **50**, which develops a potential which will make the gate electrode *g* more positive than the cathode electrode *c*. The windings **72** and **74** are inductively disposed on a saturable magnetic core **75**. Resistor **76** holds the voltage across winding **74** within the desired range; unidirectional device, such as a semiconductor diode **78**, ensures that current will flow in the proper direction in the gate circuit; and, capacitor **80** prevents damaging surge voltages from being applied to the gate-cathode junction.

However, as hereinbefore stated, the cathode spot is not immediately produced upon flow of ignitor current, with its initiation usually varying in the range of 10 to 150 microseconds after start of the ignitor current. Thus, if the controlled rectifier **50** were to be turned on as soon as the ignitor current pulse is applied to the ignitor **18**, the controlled rectifier **50** would be prematurely triggered, and voltage would be applied to auxiliary anode **20** before initiation of the cathode spot. In order to eliminate the possibility of this premature appearance of potential on auxiliary anode **20**, use is made of the voltage characteristic of the ignitor circuit. When a current pulse is applied to the ignitor **18**, the ignitor voltage increases until a cathode spot is initiated, at which time the voltage collapses or falls to the arc value. The drop in ignitor voltage, which signifies the beginning of the cathode spot, is precisely the time when it is desired that potential be applied to the auxiliary anode **20**. This voltage characteristic of the ignitor circuit may be utilized by placing the winding or coil **82** on core **75** of saturable current transformer **70**, with winding **82** being connected from the ignitor **18** to the cathode **16** through current limiting resistor **84**. As long as the ignitor **18** has a rising voltage characteristic, winding **82** keeps core **75** saturated, and winding **74** is unable to apply a gating signal to the gate *g* of controlled rectifier **50**. Once a cathode spot has been initiated, the ignitor voltage rapidly drops to the arc voltage and core **75** drops out of saturation, allowing winding **74** to produce a signal which renders controlled rectifier **50** conductive. Resistor **90** from the cathode electrode *c* of controlled rectifier **50** provides a "keep alive" path to conductor **73** to maintain controlled rectifier **50** in its conducting state until an arc is established from auxiliary anode **20** to cathode **16**. Capacitor **102** suppresses voltage spikes and transients.

When the cathode spot on cathode **16** is initiated, controlled rectifier **50** is rendered conductive, applying a potential to auxiliary anode **20**. Auxiliary anode **20** then establishes an arc to the cathode spot on the cathode **16**. The current flow from secondary winding **40** through controlled rectifier **50** to auxiliary anode **20** produces a voltage drop across the resistor **36**, which is coupled into the grid circuit, overcoming the negative bias applied to grids **22** and **24**, allowing conduction to be initiated from the cathode **16** to the anode **14** of ignitron **10**. At the conclusion of the positive voltage half cycle, the voltage or anode **14** becomes negative and the cathode spot disappears, rendering ignitron **10** nonconductive. The controlled rectifier **50** also becomes nonconductive when the positive voltage half-cycle falls to zero, and the grids **22** and **24** regain control. Sometime during the next positive half cycle, the process described above is repeated with the firing circuit pulse from firing circuit **60** establishing a cathode spot; winding **82** saturates magnetic core **75** of transformer **70** from the time the firing current starts until the cathode spot is established; winding **74** applies a gating signal to controlled rectifier **50** when the cathode spot is initiated; the auxiliary anode establishes an arc to the cathode **16**; and the grids are made positive in response to current flow in the auxiliary anode circuit, allowing conduction to take place through the ignitron **10**. Thus, it is not possible for preignition of the auxiliary anode to occur, as voltage is not applied to the auxiliary anode **20** until a cathode spot has been initiated on cathode **16**. Further, it is not possible for the grids **22** and **24** to prematurely become positive and thus lose control over the anode **14**, as the negative bias applied to grids **22** and **24** is not overcome until current flows in the auxiliary anode circuit.

While the illustration used herein shows the application of potential to the auxiliary anode **20** after initiation of the cathode spot, it is obvious that the switching means or controlled rectifier **50** could be placed in series circuit relation with any element of the ignitron where it is not desirable to have voltage appear until after the cathode spot has been established.

The invention disclosed herein precludes preignition of any of the elements of an ignitron rectifier and also prevents premature releasing of the grids. Thus, a control circuit constructed and arranged according to the principles of this invention will extend the use of the ignitron to entirely new applications and widen the range of voltage control, in addition to extending the life of the ignitron used on conventional applications by preventing an occasional preigintion and the tube deterioration which accompanies it.

Since numerous changes may be made in the above-described apparatus and different embodiments of the invention may be made without departing from the spirit thereof, it is intended that all matter contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative, and not in a limiting sense.

I claim as my invention:

1. A control circuit for rectifier tubes of the type having a plurality of electrodes including a cathode and an ignitor, comprising a source of potential, switching means having two main electrodes and a control electrode, the main electrodes of said switching means being connected in series circuit relation with one of the electrodes of said rectifier tube and said source of potential, firing means connected in circuit relation with said ignitor providing a first signal for initiating electron emission from said cathode, and means connected in circuit relation with said ignitor and the control electrode of said switching means for producing a second signal when electron emission from said cathode is initiated, said second signal changing said switching means from its nonconducting to its conducting state and electrically connecting said source of potential with the electrode of said rectifier tube connected to said switching means.

2. A control circuit for rectifier tubes of the type having a plurality of electrodes including a cathode and ignitor, comprising a source of potential, switching means having two main electrodes and a control electrode, the main electrodes of said switching means being connected in series circuit relation with one of the electrodes of said rectifier tube and said source of potential, firing means connected in circuit relation with said ignitor providing a first signal for initiating electron emission from said cathode, and means connected in circuit relation with said ignitor and the control electrode of said switching means for producing a second signal responsive to the current and collapsing voltage characteristic of said ignitor when electron emission from said cathode is established, said second signal changing said switching means

from its nonconducting to its conducting state and electrically connecting said source of potential with the electrode of said rectifier tube connected to said switching means.

3. A control circuit for rectifier tubes of the type having a plurality of electrodes including a cathode and an ignitor, comprising a source of potential, switching means having two main electrodes and a control electrode, the main electrodes of said switching means being connected in series circuit relation with one of the electrodes of said rectifier tubes and said source of potential, firing means connected in circuit relation with said ignitor providing a first signal for initiating electron emission from said cathode, and saturable core means comprising first, second, and third windings disposed in inductive relation with a saturable magnetic core, the first winding of said saturable core means being connected in circuit relation with said firing means and said ignitor, the second winding of said saturable core means being connected in circuit relation with the control electrode of said switching means, the third winding of said saturable core means being connected from the ignitor to the cathode of said rectifier tube, said third winding saturating said saturable magnetic core when said firing means applies the first signal to said ignitor until electron emission from said cathode is initiated, said second winding producing a second signal in response to the current flow produced in said first winding by said first signal when said saturable magnetic core drops out of saturation, said second signal changing said switching means from its nonconducting to its conducting state and electrically connecting said source of potential with the electrode of said rectifier tube connected to said switching means.

4. In combination, a rectifier tube of the type having an anode, cathode, ignitor, auxiliary anode, and grid means; a source of negative unidirectional potential connected in circuit relation with said grid means; a source of alternating potential; a load circuit; said source of alternating potential, load circuit, anode, and cathode being connected in series circuit relation; switching means having two main electrodes and a control electrode; the main electrodes of said switching means being connected in series circuit relation with the auxiliary anode of said rectifier tube and said source of alternating potential; firing means connected in circuit relation with said ignitor providing a first signal for initiating electron emission from said cathode; means connected in circuit relation with said ignitor and the control electrode of said switching means for producing a second signal responsive to the current and collapsing voltage characteristic of said ignitor when electron emission from said cathode is established; said second signal changing said switching means from its nonconducting to its conducting state and electrically connecting said source of alternating potential with the auxiliary anode of said rectifier tube, causing electrons to flow from said cathode to said auxiliary anode; and means responsive to electron flow from said cathode to said auxiliary anode connected in circuit relation with said grid means producing a positive potential overcoming the negative potential applied to said grid means allowing electrons to flow from said cathode to said anode through said load circuit.

5. In combination, a rectifier tube of the type having an anode, pool cathode, ignitor, auxiliary anode, and grid means; a source of negative unidirectional potential connected in circuit relation with said grid means; a

source of alternating potential; a load circuit; said source of alternating potential, load circuit, anode, and cathode being connected in series circuit relation; switching means having two main electrodes and a control electrode; the main electrodes of said switching means being connected in series circuit relation with the auxiliary anode of said rectifier tube and said source of alternating potential; firing means connected in circuit relation with said ignitor providing a first signal for initiating electron emission from said cathode; saturable core means comprising first, second, and third windings disposed in inductive relation with a saturable magnetic core; the first winding of said saturable core means being connected in circuit relation with said firing means and said ignitor; the second winding of saturable core means being connected in circuit relation with the control electrode of said switching means; the third winding of said saturable core means being connected from the ignitor to the cathode of said rectifier tube; said third winding saturating said saturable magnetic core when said firing means applies the first signal to said ignitor, until electron emission from said cathode is initiated; said second winding producing a second signal in response to the current flow produced in said first winding by said first signal when said saturable magnetic core drops out of saturation; said second signal changing said switching means from its nonconducting to its conducting state and electrically connecting said source of alternating potential with the auxiliary anode of said rectifier tube, causing electrons to flow from said cathode to said auxiliary anode; and means responsive to electron flow from said cathode to said auxiliary anode connected in circuit relation with said grid means, producing a positive potential overcoming the negative potential applied to said grid means, allowing electrons to flow from said cathode to said anode through said load circuit.

6. A control circuit for rectifier tubes of the type having a plurality of electrodes including a cathode and ignitor, comprising a source of potential, a silicon controlled rectifier having two main electrodes and a control electrode, the main electrodes of said silicon controlled rectifier being connected in series circuit relation with one of the electrodes of said rectifier tube and said source of potential, firing means connected in circuit relation with said ignitor providing a first signal for initiating a cathode spot on said cathode, and means connected in circuit relation with said ignitor and the control electrode of said silicon control rectifier for producing a second signal responsive to the current and collapsing voltage characteristic of said ignitor when electron emission from said cathode is established, said second signal changing said silicon controlled rectifier from its nonconducting to its conducting state and electrically connecting said source of potential with the electrode of said rectifier connected to said switching means.

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