Oct. 20, 1953 W. O. FULLERTON 2,656,487

VOLTAGE SUPPLY CONTROL CIRCUIT

Filed June 29, 1950 2 Sheets-Sheet 1

FIG. 1

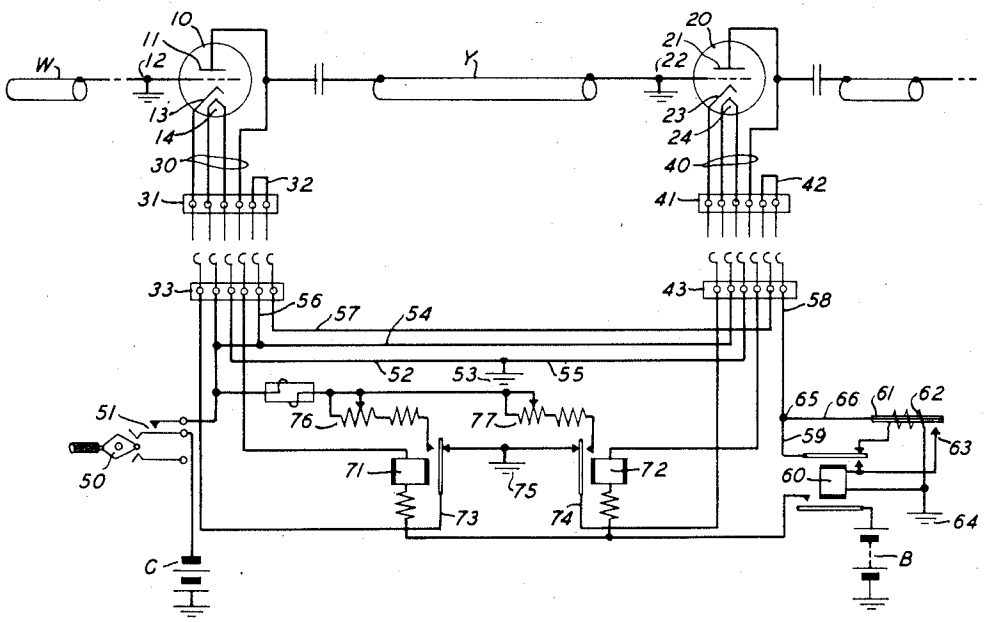

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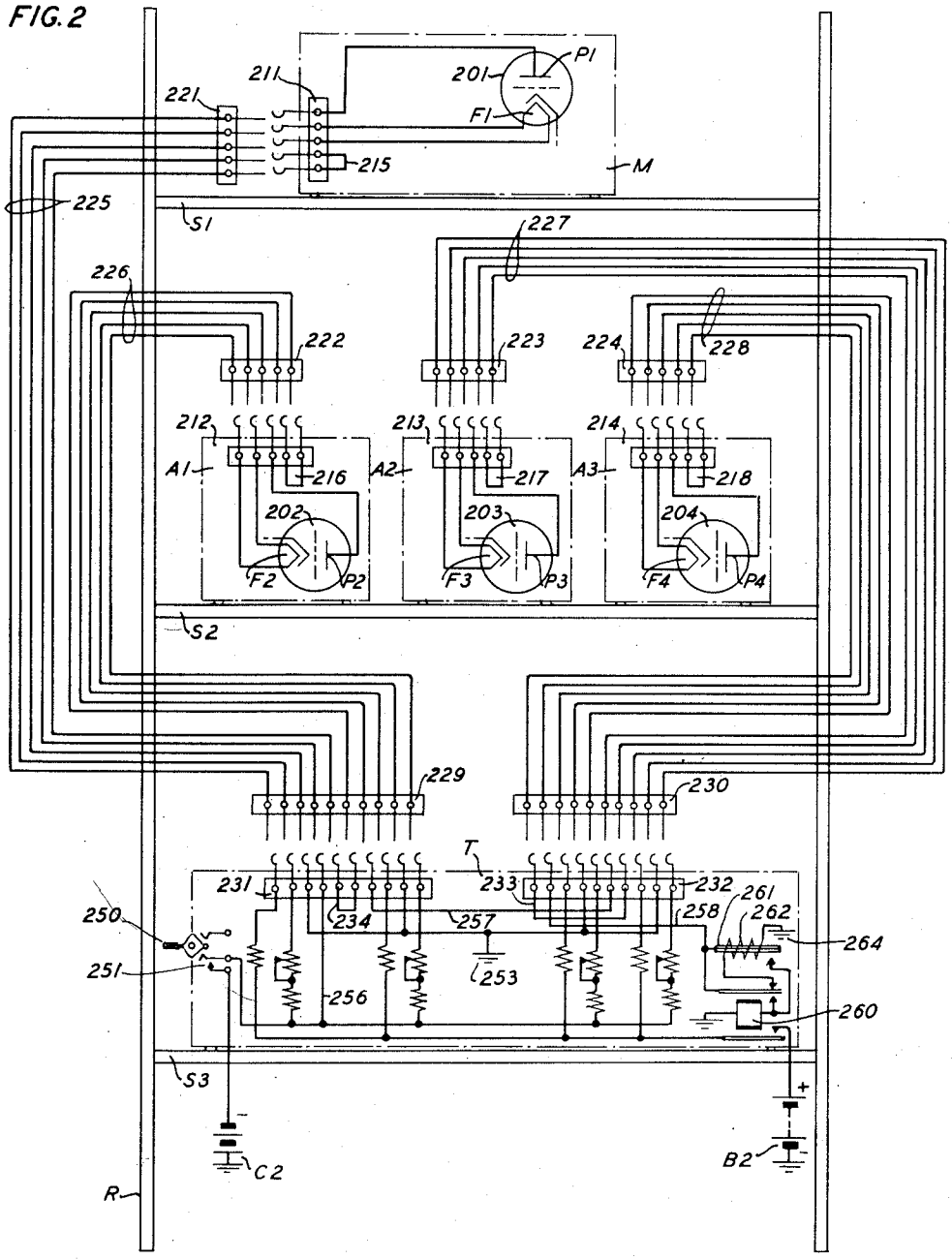
FIG. 2



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2,656,487

VOLTAGE SUPPLY CONTROL CIRCUIT

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3 Claims. (Cl. 315—104)

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This invention relates to control circuits and, more particularly, to control circuits of the interlocked type. The invention also relates to sequentially operating control circuits of the interlocked type wherein one element must be energized before another element is energized.

The invention may be used with various types of equipment and apparatus, such as electron discharge devices. When used with electron discharge devices, the invention is particularly useful for controlling automatically in proper sequence the application of electric energy to electrodes of such devices. Accordingly, for the purpose of explaining its principles and features of operation, the invention will be described with reference to its use with electron discharge devices.

The desirability of automatically delaying the application of electric energy to one electrode of an electron discharge device for an assigned interval of time after the application of electric energy to another electrode of the same device is well known. Such sequential application of energy is important in the case of electron discharge devices of the thermionic cathode type for automatically delaying the application of electric potential to the anode of such a device until its cathode has been heated to its proper operating temperature. This sequential operation is particularly important when the grid of an electron discharge device is closely spaced with respect to its anode and is even more closely spaced with respect to its cathode, because, if either the anode or cathode potentials should be applied to their respective electrodes before the cathode had been properly heated, the grid would be physically damaged.

Accordingly, it is an object of this invention to provide a control circuit with interlocking means whereby the deenergization of one portion of the circuit causes another portion of the circuit to become deenergized.

Another object of the invention is to provide a sequentially operating control circuit with means whereby one portion of the circuit is not energized until another portion of the circuit has been energized.

A further object is to provide a control circuit for automatically delaying the application of anode and cathode potentials to an electron discharge device for a preassigned interval of time after the application of cathode heating current to the device.

An additional object is to provide a control circuit for discontinuing the application of anode and cathode potentials to an electron discharge

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device in the event of an interruption in its cathode heating circuit.

Still another object is to provide a circuit with control means for applying cathode and anode potentials from common supply sources to a plurality of electron discharge devices only after the expiration of an assigned interval of time after a circuit has been closed to connect cathode heating current to the devices and to further provide the two circuits with interlocking means whereby an interruption of the cathode heating current supplied to any one of said devices effects an interruption of the supply of anode and cathode potentials to all of the devices.

These and other objects of the invention are accomplished by connecting the energizing circuit of a control relay in parallel with the cathode heating circuit of an electron discharge device. This energizing circuit includes delay means of the thermal bimetallic type. An armature of the control relay controls a circuit for applying an electric potential to the anode of the device. Another relay is connected in the anode circuit for controlling the application of a different electric potential to the cathode of the device. Thus, when current is supplied to the cathode heating circuit, the same current will also be delivered to the control relay which will operate its armature at the expiration of the delay period to apply voltage to the anode of the electron discharge device. As soon as the anode current rises to an assigned value, the relay in the anode circuit will operate its armature to apply voltage to the cathode of the same electron discharge device. Since the circuit for energizing the control relay is interlocked with the circuit for heating the cathode, any interruption of the cathode heating current will cause the control relay to release its armature thereby opening the anode circuit which, in turn, causes the anode relay to release its armature to open the cathode circuit. When the cathode heating current is restored, the sequential application of potentials to the anode and cathode will not occur again until after the expiration of the delay period required for energizing the control relay. In certain types of equipment, a plurality of electron discharge devices are employed with common sources of anode and cathode potentials and cathode heating current. In such cases, additional interlocking means are provided for interrupting the supply of anode and cathode potentials to all of the electron discharge devices whenever there is an interruption in the cathode heating current supplied to any one of the electron discharge devices.

These and other features of the invention are more fully discussed in connection with the following detailed description of the drawing in which:

Fig. 1 is a simplified circuit schematic of one embodiment of the invention; and

Fig. 2 illustrates a more complex embodiment of the invention.

In Fig. 1, two electron discharge devices of the thermionic cathode type are represented by the tubes 10 and 20 each having an anode 11—21, a control grid 12—22, a cathode 13—23, and a cathode heating filament 14—24. Positive operating voltage for the anodes 11—21 is supplied from a 250-volt battery B, negative bias potential for the cathodes 13—23 is supplied from an 11-volt battery C, and heating current for the cathode heating filaments 14—24 is also supplied from the battery C. For the purpose of explanation, the tubes 10 and 20 may be considered as constituting a two-stage broad-band microwave amplifier in which signals from any suitable source, such as the wave guide W, are applied to the control grid 12 for amplification in the tube 10 and are then supplied over another wave guide Y extending from the anode 11 to the control grid 22 for further amplification in the tube 20.

In this particular embodiment of the invention, the tubes 10 and 20 are of the type disclosed in Patent 2,502,531 issued April 4, 1950, to J. A. Morton et al., and have their electrodes closely spaced; that is, the grids 12—22 are located very close to the anodes 11—21 and are located even more closely with respect to the cathodes 13—23. Due to this close spacing of the electrodes, it is important that the application of operating potential to the anodes 11—21 be delayed until the cathodes 13—23 have been heated to their proper operating temperature by their respective heaters 14—24. It is also important that the application of bias potential to the cathodes 13—23 be delayed until the anode current in their respective tubes 10—20 has risen to a proper operating value. If either of these precautions is not observed, electrostatic charges are liable to accumulate between the anodes 11—21 and the grids 12—22 or between the grids 12—22 and the cathodes 13—23 with the result that the grids 12—22 would be physically damaged. It is therefore desirable to employ a control circuit for automatically applying in proper sequence electric energy to the electrodes of the tubes 10 and 20.

In the control circuit shown in Fig. 1, the electrodes, including the heater filaments, of each of the tubes 10 and 20 are connected individually to electric conductors, the conductors associated with each tube 10—20 being grouped in the form of a cable 30—40. Each of the cables 30—40 is provided at its end with a multi-element terminating plug 31—41. It is to be noted that each of the terminating plugs 31—41 has two of its elements electrically connected together by a short-circuiting conductor 32—42 to form interlocking means described hereinafter. The plugs 31—41 are adapted to be detachably inserted into multi-element receptacles 33—43 located adjacent thereto, each of the elements of each of the receptacles 33—43 being adapted to make electric connection with a corresponding element in its respective associated plug 31—41. The elements of the receptacles 33—43 are connected individually to electric conductors which supply electric energy thereto from batteries B and C in a manner that will now be described.

In operating the control circuit of Fig. 1, the first step is to insert the plugs 31—41 into the receptacles 33—43 thereby electrically connecting the conductors in the cables 30—40 to the conductors extending from the elements of the receptacles 33—43. The next step is to operate manually a conventional toggle switch 50 for closing a normally open control contact 51. The closing of the contact 51 completes a circuit extending from battery C, over the filament elements of receptacle 33 and plug 31, through the heating element 14, and then over conductor 52 to ground 53. The actuation of contact 51 also closes a similar circuit for current from battery C to flow along conductor 54, over the filament elements of receptacle 43 and plug 41, through the heating filament 24, and then over conductor 55 to ground 53. Thus, heating current from battery C is applied substantially simultaneously over parallel circuits to the filaments 14 and 24 for heating the thermionic cathodes 13 and 23. Since these parallel circuits are not interlocked, the withdrawal of one of the plugs 31—41 from its respective associated receptacle 33—43 will affect the opening of only the filament circuit associated therewith thereby permitting the other filament circuit to remain closed.

The cathodes 13 and 23 do not become heated to their proper operating temperature immediately upon the closing of the filament circuits but instead must be heated for a short interval of time in order for their temperature to be raised to the proper point. It is therefore desirable to provide means for delaying the application of anode and cathode potentials for a corresponding interval of time so that these electrodes will not be energized before the cathodes have been heated to their proper operating temperature. In this embodiment of the invention, the delay means for accomplishing this result includes a relay 60 having its energization controlled by thermal delay means of the bimetallic type comprising a heat-responsive bimetallic strip 61 composed of any two suitable electrically conductive metals having different thermal expansion coefficients. Associated with the bimetallic member 61 is a heating element 62 of any suitable construction, such as a resistance wire which becomes hot in response to the flow of electric current thereover. This heating element 62 is disposed in any appropriate heat-transfer relation with respect to the heat-responsive member 61 for transferring heat thereto. The member 61 is designed in such a manner that, upon being heated by the heat transferred thereto by the element 62, it gradually bends downward until it finally engages its associated contact 63 to complete an electric circuit described hereinafter. The element 62 and the member 61 are so constructed and proportioned that the interval of time between the energization of element 62 and the engagement of member 61 with its contact 63 is substantially the same as the interval of time required to heat the cathodes 13—23 to their proper operating temperature.

The circuit for energizing the heating element 62 extends from battery C in parallel with the cathode heating circuits. Thus, when the control contact is closed in the manner described above, a circuit is completed for current from battery C to flow along conductor 56 and associated elements of receptacle 33 and plug 31, along the short-circuiting plug conductor 32, through plug 31 and receptacle 33, along conductor 57, over elements of receptacle 43 and plug 41, along the second coupling conductor 42, out through

plug 41 and receptacle 43, along conductors 58 and 59, over the top armature and outer contact of relay 60, and then through the heating element 62 to ground 64. It is to be noted that the elements of the plugs 31—41 that are connected by the short-circuiting conductors 32—42 constitute interlocking means whereby the energization of the thermal delay device 61—62 is prevented if one of the cathode heating circuits extending to either of the filaments 14—24 is open due to the fact that its associated plug 31—41 is not inserted in its respective associated receptacle 33—43.

The closing of the above-described circuit for energizing the heating element 62 causes the element 62 to generate heat which is transferred to the heat-responsive member 61. At the end of the assigned delay period, the bimetallic member 61 engages its associated contact 63 to close a path for energizing the relay 60. This energizing circuit extends from the junction point 65 located in the circuit for energizing the heating element 62, along conductor 66, over member 61, contact 63, and then through winding of relay 60 to ground 64. Upon the closing of this energizing circuit, relay 60 operates both of its armatures to engage their inner contacts.

When the top armature of relay 60 moves down out of engagement with its outer contact, it disconnects battery C from the heating element 62 thereby causing both element 62 and member 61 to cool. The engagement of the top armature of relay 60 with its inner contact closes another path for energizing relay 60. This second path extends from the junction point 65, along conductor 59, top armature and inner contact of relay 60, and then through the winding of relay 60 to ground 64. Relay 60 will now be supplied with energizing current over these two parallel paths simultaneously for a short period of time. When the bimetallic member 61 has cooled sufficiently to move out of engagement with its associated contact 63, it thereby opens the upper parallel path which includes the conductor 66. The lower parallel path, which includes the conductor 59, will remain closed until either the control contact 51 is opened or one of the plugs 31—41 is withdrawn from its respective associated receptacle 33—43.

The engagement of the bottom armature of relay 60 with its contact applies electric energy from battery B over obvious parallel circuits extending through the windings of relays 71—72 and over elements of receptacles 33—43 and plugs 31—41 to the anodes 11—21. Thus, operating potential from battery B is applied to the anodes 11—21 an assigned interval of time after electric energy from battery C has been applied to the cathode heating filaments 14—24.

As was stated above, it is important that the application of bias potential to the cathodes 13—23 be delayed until the anode current in their respective tubes 10—20 has risen to a proper operating value. This is accomplished by means of the relays 71—72 which have their windings connected in the anode circuits. When the equipment is in an unoperated condition, the relays 71—72 are not energized and, consequently, their armatures are in engagement with their outer contacts thereby closing parallel circuits extending from the cathodes 13—23, through elements of the plugs 31—41 and receptacles 33—43, and then along conductors 73—74, respectively, to ground 75. Thus, the cathodes 13—23 are at ground potential when the equipment is in an

unoperated condition. The relays 71—72 are marginal in that they are so adjusted that they will not operate their armatures until the electric energy flowing through their windings exceeds an assigned value. In the present embodiment of the invention, each of the relays 71—72 is adjusted to operate its armature when the plate current of its associated tube 10—20 rises to a value of approximately 5 milliamperes.

When either one of the relays 71—72 becomes sufficiently energized, its armature is moved away from the outer contact to engage the inner contact. The removal of the armature from its outer contact disconnects the associated cathode 13—23 from ground 75. The engagement of the actuated armature with its inner contact closes a circuit for cathode bias potential to be applied from battery C, through the respective associated series-connected potentiometer 76—77, along the respective conductor 73—74, and then over the elements of the associated receptacle 33—43 and plug 31—41 to the respective cathode 13—23. Since each of the tubes 10—20 is of the type having its plate current determined by the potential difference between its grid 12—22 and cathode 13—23, the application of bias potential to the cathodes 13—23 tends to stabilize the plate current in the tubes 10—20.

It is to be noted that, since the sequentially operating control circuit of this invention includes interlocking means comprising the short-circuited elements of the plugs 31—41, any interruption of the cathode heating current supplied to either one of the heating filaments 14—24 will effect an interruption of the supply of anode and cathode potentials to both of the tubes 10—20. For example, if the supply of heating current to the filament 14 of the tube 10 is interrupted by the withdrawal of its associated plug 31 from the receptacle 33, then the circuit for energizing relay 60 will be open at those elements of receptacle 33 that are connected to the conductors 56 and 57. Thus, since the short-circuiting conductors 32 and 42 are connected in series, the removal of either one from the energizing circuit of relay 60 will cause the relay 60 to release its armatures even though the other remains connected to the associated elements of its respective associated receptacle 33—43. The release of the bottom armature of relay 60 disconnects battery B from the circuits extending through the windings of relays 71 and 72 to the anodes 11—21. This, in turn, effects a release of the armatures of relays 71 and 72 thereby disconnecting the cathode conductors 73 and 74 from the biasing circuit extending from battery C through the potentiometers 76 and 77 and connecting the cathode conductors 73 and 74 to ground 75. At the same time, the release of the top armature of relay 60 disconnects the conductor 59 from the winding of relay 60 and connects it to the heating element 62 in the thermal delay device 61—62.

When the cathode heating circuit is again closed by the reinsertion of the plug 31 in the receptacle 33, the series circuit through the coupling conductors 32—42 will again be closed to apply current from battery B over the conductor 59 to the thermal delay device 61—62 to recycle its operation. At the expiration of the delay period described above, relay 60 again becomes energized and operates its armatures to effect a repetition of the above-described sequential application of potentials to the anodes 11—21 and cathodes 13—23.

The invention is particularly useful when employed with equipment having a number of electron discharge devices which require interlocking of their electric energy supply circuits. Such an embodiment of the invention is shown in Fig. 2, in which an equipment rack R is provided with a plurality of transverse shelves S1, S2, and S3 for supporting several related equipment units. The top shelf S1 supports a transmitter-modulator unit M; the middle shelf S2 supports three amplifier units A1, A2, and A3 constituting a three-stage amplifier; and the bottom shelf S3 supports a transmitter control unit T. As is indicated in Fig. 2, the transmitter-modulator unit M and each of the three amplifier units A1, A2, and A3 include electron discharge devices 201, 202, 203, and 204, respectively, which may be of the type disclosed in the above-mentioned patent to J. A. Morton et al. In each of these units, the anodes P1, P2, P3, and P4 and cathode heating filaments F1, F2, F3, and F4 of the tubes 201, 202, 203, and 204 are connected to elements of respectively associated multi-element receptacles 211, 212, 213, and 214. In order to simplify the drawing, the grid circuits of the tubes 201, 202, 203, and 204 have not been shown in Fig. 2. For the same reason, the cathode biasing circuits of the tubes 201, 202, 203, and 204 have not been shown, as it is to be understood that they are of the same type as those shown in Fig. 1; that is, each cathode is connected to ground over the armature of a relay, similar to the relays 71 and 72 shown in Fig. 1, which, upon being energized by its respective associated plate current, operates its armature to connect biasing current from battery B2 to the cathode. It is to be noted that two of the elements of each of the receptacles 211, 212, 213 and 214 are electrically connected together by coupling conductors 215, 216, 217, and 218 to form interlocking means similar to those described above.

Associated with each of the receptacles 211, 212, 213, and 214 is a multi-element plug 221, 222, 223, and 224 adapted to be detachably inserted therein. The elements of the plugs 221, 222, 223, and 224 are connected individually to electric conductors which are grouped in the form of cables 225, 226, 227, and 228 and which are connected at their other ends to elements of double plugs 229 and 230. The plugs 229 and 230 are adapted to be detachably inserted into multi-element receptacles 231 and 232 associated with the transmitter control unit T. Two of the elements in each of the receptacles 231 and 232 are connected together by coupling conductors 234 and 233, respectively, to form additional interlocking means as will be described hereinafter.

The transmitter control unit T also includes a thermal delay device 261—262, similar to the device 61—62 shown in Fig. 1, for controlling the energizing circuit of a relay 260.

When all of the plugs 221, 222, 223, 224, 229 and 230 have been inserted in their respective associated receptacles 211, 212, 213, 214, 231, and 232, the operation of the equipment can be initiated by manually actuating a conventional toggle switch 250 to close a normally open control contact 251. The closing of the contact 251 causes heating current from battery C2 to be applied over obvious parallel circuits through the individual cathode heating filaments F1, F2, F3, and F4, and then to ground 253. At the same time, current from battery C2 is also applied along conductor 256, over the elements of receptacle 211 that are connected by the short-circuiting conductor 215, over elements of receptacle 231 that are connected by conductor 234, similar elements of receptacle 212 connected by conductor 216, along conductor 257, along the coupling conductor 217 associated with receptacle 213, over the coupling conductor 233 associated with receptacle 232, over coupling conductor 218 associated with receptacle 214, along conductor 258, over the top armature of relay 260, and then through the heating element 262 to ground 264.

After being heated for an assigned period of time, similar to that required for operating the thermal delay device 61—62 described above, the bimetallic member 261 engages its contact to close a circuit for energizing relay 260. Relay 260 operates its armatures in the same manner as that described above for relay 60, the actuation of its bottom armature applying potential from battery B2 over obvious parallel circuits to the anodes P1, P2, P3, and P4. Thus, operating potential from the battery B2 is not applied to the anodes P1, P2, P3, and P4 until an assigned interval of time after the application of current from battery C2 to the cathode heating filaments F1, F2, F3, and F4. As was stated above, it is to be understood that when the anode current in any one of the tubes 201, 202, 203, and 204 rises to an assigned value, a relay, similar to relays 71 and 72 in Fig. 1, is caused to operate its armature to disconnect its associated cathode from ground and to connect it to the battery C2.

Since this sequentially operating control circuit includes the interlocking means described above and since these interlocking means are all connected in series, any interruption in the supply of current from battery C2 to any of the cathode heating filaments F1, F2, F3, or F4 will effect an interruption of the supply of anode and cathode potentials to all of the tubes 201, 202, 203, and 204. For example, if the supply of current to the filament F1 is interrupted by the withdrawal of the plug 221 from the receptacle 211, then the energizing circuit for relay 260 will be open at the two bottom elements of plug 221 with the result that relay 260 will release its armatures. The release of the bottom armature of relay 260 opens the circuit from battery B2 to the anodes P1, P2, P3, and P4 and this, in turn, effects the disconnection of battery C2 from the associated cathodes in the manner explained above in connection with the description of the circuit shown in Fig. 1. When the plug 221 is reinserted in its receptacle 211, the thermal delay device 261—262 recycles its operation to effect a repetition of the above-described sequential application of potentials to the anodes and cathodes of the tubes 201, 202, 203, and 204.

What is claimed is:

1. In combination, a plurality of thermionic tubes each having a filament and an anode, a plurality of cables each comprising a plurality of electric conductors, the conductors in each cable being connected to the filament and anode of a different one of said tubes, each of said cables having a multi-element terminating plug with two of its elements short-circuited, a plurality of multi-element receptacles for receiving said plugs, each of the elements in each of said receptacles being adapted to make electric connection with a corresponding element in the associated plug, a source of filament potential, a first circuit for connecting said source to a filament element in each of said receptacles, a source of anode potential, a second circuit for connecting

said source of anode potential to an anode element in each of said receptacles, said second circuit being normally open, a relay having a first armature adapted to close said second circuit, a third circuit for energizing said relay, said third circuit having two normally open parallel paths, a thermal delay device for closing the first of said paths for energizing said relay, and a fourth circuit for connecting said source of filament potential to said thermal delay device for energization thereof, said fourth circuit including said short-circuited elements of each of said plugs and the corresponding receptacle elements connected in series, said relay having a second armature actuable in response to the energization of said relay for disconnecting said thermal delay device from said fourth circuit and for closing the second of said parallel paths.

2. In combination, first and second sources of electric energy, a plurality of thermionic tubes each having a heating filament and an anode, a corresponding plurality of detachable pairs of multi-element circuit connectors, each of the elements in each of said connectors being adapted to make electric connection with a corresponding element in the companion connector when the two connectors of a pair are in engagement, one connector in each of said pairs having an element connected to the filament of a respectively different one of said tubes and the other connector in each of said pairs having a corresponding element coupled to said first source whereby the engagement of the two connectors in any of said pairs effects the connection of the filament in the corresponding tube to said first source, a plurality of circuits each extending from a respectively different one of said anodes to said second source, a relay adapted when energized to effect the closure of all of said anode circuits and adapted when unenergized to effect the opening of all of said anode circuits, an energizing circuit extending from said first source for energizing said relay, and control means for limiting the closing of said anode circuits by said relay to periods when all of said filaments have been connected to said first source, said control means comprising two short-circuited elements in one connector of each of said pairs and circuit means for connecting said short-circuited elements and their companion elements in the other connectors of each of said pairs in series with said first source and the energizing winding of said relay whereby the disconnection of any one of said filaments from said first source caused by the disengagement of its associated pair of connectors effects the opening of said relay energizing circuit.

3. The combination recited in claim 2 and having a cathode in each of said thermionic tubes, each of said cathodes having a supply circuit extending through elements of respectively different pairs of said connectors, and a plurality of marginal supply relays each adapted when unenergized to connect a respectively different one of said supply circuits to ground and adapted when energized to connect its associated supply circuit to said first source, each of said supply relays having an energizing winding connected in a respectively different one of said anode circuits whereby the energization of all of said supply relays is limited to periods when all of said anode circuits are closed, each of said marginal relays being so adjusted as to operate only in response to the flow in its respectively associated anode circuit of electric current having a magnitude in excess of an assigned value.

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