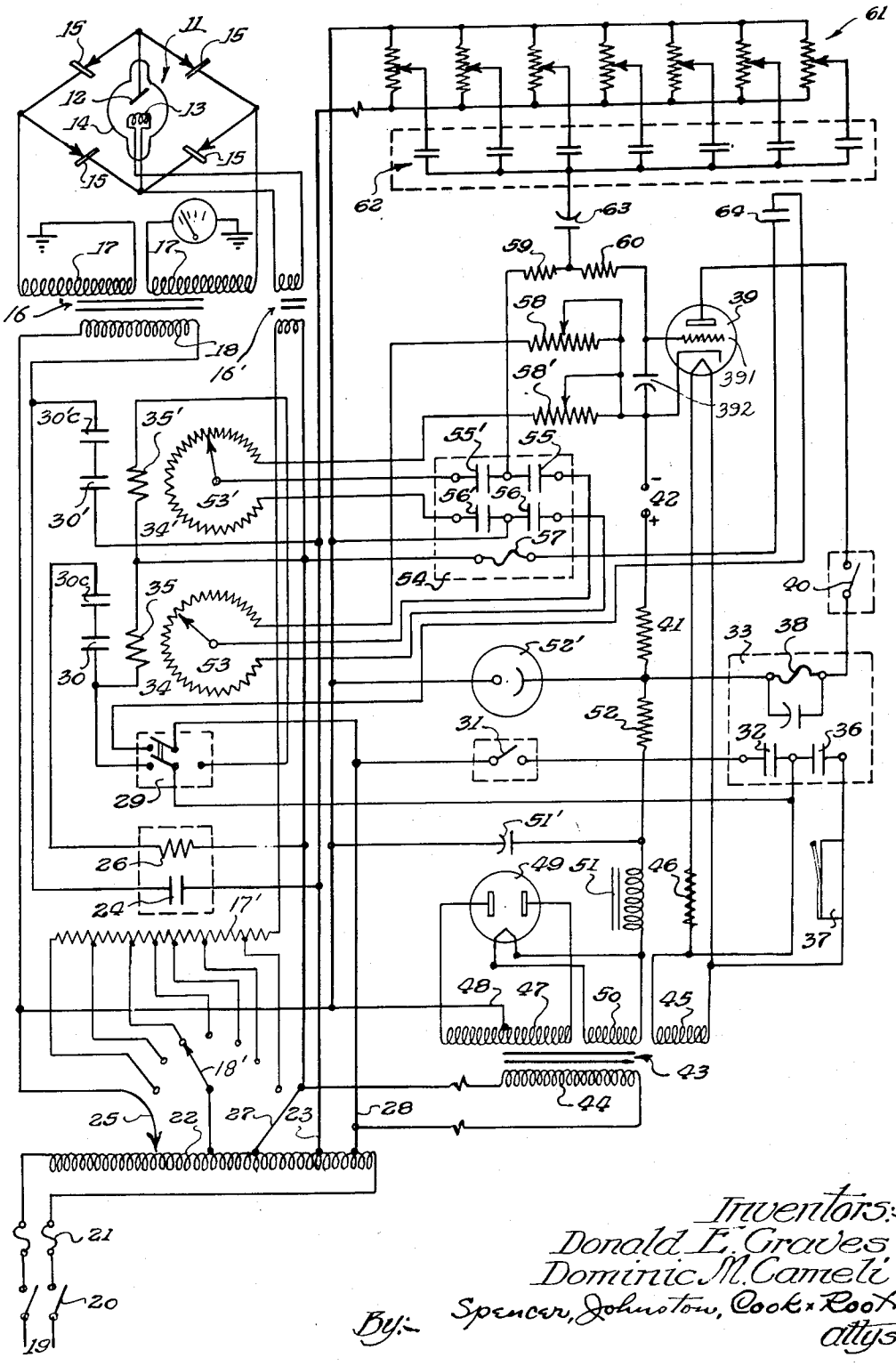
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ELECTRICAL PROTECTIVE SYSTEM

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ELECTRICAL PROTECTIVE SYSTEM

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The present invention relates in general to systems for supplying power to electrical load devices, and has more particular reference to the provision of novel protection means for allowing the delivery of electric power to a load device only in amounts, insufficient to dangerously overload the device, during a selected operating time interval.

While the teachings of the present invention may be applied in any system for the supply of electrical power to a load of the sort operable for short intervals under conditions of substantial overload, the invention has particular application in power supply systems for X-ray generators, and like electrically energized devices, the operation of which at exceedingly high energy levels during short operating intervals, is desirable or necessary, but which, if operated continuously, or for too long an operating interval, at such high energy levels, may become irreparably damaged.

An X-ray generator commonly comprises a tube embodying an anode and a cooperating cathode enclosed in a sealed and evacuated envelope. Such a tube operates for X-ray production as the result of impingement, upon the anode, of electrons emitted by the cathode. During the operation of the tube for X-ray production, electrons emitted by and at the cathode are impelled toward and caused to impinge upon the anode, under the influence of electrical potential of suitable polarity maintained between the anode and cathode. The cathode comprises an electron emitting element, usually in the form of a filament adapted to be electrically energized or excited for electron emission.

During operation of the generator, heat is developed therein as the result of electron impingement, at high velocity, on the anode. The amount of operating heat thus generated is a function of the rate of electron impingement on the anode, which, in turn, is a function of the electron emission rate of the cathode, and also of the electron impelling voltage maintained between the anode and cathode for the operation of the device. The electron emitting rate of the cathode, in turn, is a function of cathode excitation, and may be expressed in terms of electrical current employed in exciting the cathode for electron emission.

The heat generated as the result of operating an X-ray tube may be of the order of the melting point of the anode metal, and it is commonly dissipated as rapidly as possible, from the anode, through the walls of the tube, or by the circulation of a cooling fluid in heat exchange relation with the anode, or by other heat dissipating means, the generator tube being ordinarily designed to dissipate operating heat therefrom, as rapidly as possible, within the heat transfer limits of the dissipating means. An X-ray generator, however, is usually operated during relatively short intervals of time, at relatively high energy input levels, especially where rays of intense penetrating character are required, ray intensity being also a function of the rate of electron impingement on the anode. Desirable operating energy levels may be of an order such that, if continuously

applied to the tube during an unduly extended operating interval, the temperature thereof, because of the limited heat dissipating ability of the tube, may increase above the melting point of its constituent parts, thereby damaging or destroying the X-ray tube.

An important object of the present invention is to provide means for limiting the amount of electrical energy that may be supplied to an electrical load device, to a quantity such that the device may not be operated under dangerously overloaded conditions during a limited period for which it is set to operate; a further object being to provide apparatus which will allow the device to be operated, at any time, at a maximum input energy level just short of the safe heat absorbing capacity of the device during a limited operating interval.

Another important object is to provide protective means for preventing the delivery of electrical energy to an X-ray tube if the same be adjusted for operation, at a dangerously high energy level, during an unduly extended interval of operation; a further object being to allow operation of the device in any adjusted condition as to cathode emission rate, operating anode cathode potential, and operating time interval, that will not result in dangerously overloading the device during a selected operating time interval.

Another important object is to provide protective means, adjustable in accordance with the variably adjustable load settings of an adjustable load device, to prevent the device from being dangerously overloaded during a limited operating interval.

The foregoing and numerous other objects, advantages, and inherent functions of the invention will become apparent as the same is more fully understood from the following description, which, taken in connection with the accompanying drawing, discloses a preferred embodiment of the invention.

The single figure of the drawing is a diagrammatical representation of a protective system embodying the present invention.

To illustrate the invention, the drawing shows an adjustable load device comprising, in the present instance, an X-ray generator tube 11, including an anode 12 and an electron emitting cathode shown as a filament 13, adapted to be suitably energized for operation as a cathode. The anode and cathode may be conventionally enclosed in a sealed, evacuated envelope 14 and electrically connected with a suitable source of energizing power. The X-ray generator tube 11 may be operated either as a self-rectifying device, by connecting the anode and cathode directly with a suitable source of alternating current power, or it may be operated by application of direct current power between the anode and cathode. As shown, the anode and cathode of the device 11 are interconnected with the direct current output of a suitable full wave rectifying system, comprising the rectifiers 15 and energized by alternating current power through a suitable transformer 16. The secondary or high voltage windings 17 of this transformer are suitably connected with the input side of the full wave rectifying system, the primary winding 18 of the transformer being connected with a source of relatively low voltage alternating current power, through instantaneous overload protective means hereinafter more particularly described.

The tube 11 may be operaed as an X-ray generator by energizing the cathode 13 for the emission of electrons and by simultaneously applying relatively high electric potential between the anode and cathode of the tube to impel cathode emitted electrons at high velocity upon the anode. For purposes of adjustment of the cathode electron emission rate, conventional means may be provided for energizing it at any selected one of a number of cathode exciting levels, and conventional means may

also be provided for selectively adjusting the anode-cathode operating voltage.

When an X-ray generating tube is operated as such, heat is released therein at a rate many times greater than the heat dissipating capacity of the tube. It is not only necessary to allow the tube to cool off from time to time to prevent the same from reaching destructively high temperatures as the result of operation at too frequent intervals, but it is also necessary to limit the amount of energy delivered to the tube, during any single time limited period of continuous operation, to an amount such that the tube, during the operating interval, may not reach a dangerously high temperature at the anode.

While a certain amount of heat is generated in the tube as the result of the release therein of cathode exciting energy, such heat is relatively insignificant when compared with the enormously larger quantities of heat developed at the anode as a result of X-ray producing electron impingement thereon. For practical purposes in determining the dangerous heat loading of a tube, operated during a limited time interval, cathode energizing heat may be disregarded. The cooling characteristics of the tube may also be disregarded, as they have relatively small effect during short operating time intervals. Thus it is that the dangerous heating effect, due to tube operation during limited, relatively short time intervals, may be measured, with sufficient exactness for practical purposes, as an approximation of the number of electrons impinging on the anode during the operating interval. This, as previously suggested, is a function of anode-cathode voltage, cathode exciting current, and the operating time interval; and the present invention proposes apparatus automatically adjustable, in accordance with the preselected operating interval during which the tube is to be operated, to limit the amount of electron impelling energy that may be applied between the anode and the cathode of the device, during such operating interval, whereby to prevent operation of the tube under dangerous overload conditions.

To this end, operating energy may be delivered between the anode and cathode of the tube through the transformer **16** from any suitable source of alternating current power **19**, which may be connected, as through switch means **20** and overload protection devices **21**, to an auto transformer **22**. The auto transformer may have a tap connection **23** connected with one side of the primary winding **18** of the transformer **16**, as through a normally open switch **24**. The auto transformer may also be provided with an adjustable tap connection **25** electrically connected with the other side of the transformer winding **18**, whereby anode-cathode operating power, at potential determined by adjustment of the connection **25**, may be supplied to the X-ray tube under the control of the switch **24**, said switch being associated with a corresponding relay coil **26**, adapted, when electrically energized, to close its associated switch. The adjustable tap connection **25** thus comprises a selector switch for determining the operating voltage applicable between the anode and cathode of the X-ray tube **11**. The relay coil **26** is connected in a corresponding actuating circuit, extending between tap connections **27** and **28**, on the auto transformer, and controlled by a preferably single pole, double throw selector switch **29**. The relay coil **26**, on one side thereof, may be connected with the auto transformer tap **27**, and may also be connected, through a pair of timer switches **30** and **30***c*, to a selecting contact of the switch **29**, the pole of which is connected with the auto transformer tap **28** through a manually operable switch **31** and the normally closed switch **32** of a control relay **33**.

A pair of timer switches **30′** and **30′***c*, similar to switches **30** and **30***c*, may be connected in parallel relation with respect to the switch **24**, between the primary **18** of the transformer **16** and the auto transformer tap **23**. Consequently, anode-cathode operating power may be delivered, either under direct control of the timer switches **30′** and **30′***c*, or under control of the switch **24** indirectly controlled by the timer switches **30** and **30***c*. It will, of course, be obvious that the timer switches **30′** and **30′***c* could also be connected to indirectly control anode-cathode power, through a relay switch, like switch **24**, if desired.

It will be seen from the foregoing that, when and so long as the switches **31** and **32** are closed, the operating coil **26** of the switch **24** may be energized under the control of the timer switches **30** and **30***c*, depending upon the selectively adjusted condition of the switch **29**. The timer switches **30** and **30***c* respectively form operating parts of a synchronous timing mechanism **34**. The timer switches **30′** and **30′***c* form like operating parts of an impulse timer mechanism **34′**. The switches **30** and **30′** are normally open switches, which are adapted to close when and so long as coils **35** and **35′**, associated therewith, are electrically energized. The switches **30***c* and **30′***c* are normally closed switches adapted to be opened by and during the operating cycle of the timing mechanisms in which the same are operating parts. These separate timing devices are adapted to be adjusted for operation so that, when released, they will operate to close their respective switches **30** and **30′** and then open switches **30***c* and **30′***c* after a predetermined time interval.

The synchronous timing mechanism **34** is adjustable to operate its associated switches **30** and **30***c* during intervals measured in terms of elapsed time. The impulse timer **34′** is adjustable to operate its associated switches **30′** and **30′***c* during time intervals measured in terms of the number of energy impulses transmitted at predetermined frequency during the selected interval to be measured. Synchronous and impulse timing mechanisms of the sort herein contemplated are respectively illustrated and described in United States Patents No. 1,740,405 and No. 2,325,860.

Each of the timers **34** and **34′** respectively includes a relay coil **35** and **35′** operatively associated respectively with the switches **30** and **30′**, to close same when energized, and to release the adjusted mechanism for the performance of its timing function, said coils being connected between the taps **27** and **28** under control of the switches **29**, **31**, and **32**. Accordingly, as determined by the selector switch **29**, one or other of the coils **35** and **35′** will be energized to close its associated switch **30** or **30′** and start the corresponding timing device in operation, upon closure of the manual switch **31**, providing, of course, that the switch **32** is then in closed condition. Such closure of a switch **30** or **30′** will energize one or other of the coils **35** or **35′** and operate one or other of the timer mechanisms to deliver operating power through the transformer **16** to the anode and cathode of the X-ray tube. As a result of the operation of the timing device, the switch **30***c*, or **30′***c*, as the case may be, will be opened mechanically, upon the expiration of the tube operating interval for which the timing device shall have been previously adjusted, thereby disabling the supply of operating power in the anode-cathode circuit of the tube **11**.

The overload protective system of the present invention comprises apparatus automatically adjustable, in response to adjustment of the timing mechanism, adjustment of the anode-cathode electron driving voltage supply, and adjustment of cathode excitation, to prevent operation of the X-ray generating tube **11** in the event that such selective adjustments are made in manner which would result in dangerously overloading the X-ray generating tube **11** if, so adjusted, it were to be operated. When such a dangerous condition of adjustment occurs, the protective apparatus operates to open the exposure control circuit at the switch **32**, thereby making it impossible to operatively energize the X-ray generating tube **11** by closure of the manual control switch **31**. At the same time, a warning signal is caused to operate to indicate faulty adjustment of the apparatus.

To these ends, the relay **33**, in addition to the normally

closed switch 32, comprises a normally open switch 36, for controlling a warning device 37, which may conveniently comprise a buzzer or other audible or visual signalling means. The relay 33 also includes a switch operating coil 38, which, when energized, serves to open the switch 32 and close the switch 36. The relay coil 38 is connected in a series circuit between the anode and cathode of a thyratron tube 39, such series circuit preferably including a manual reset switch 40, a control resistor 41, and a source of direct current plate circuit power 42, in series with the coil 38. The thyratron tube has a control grid 391 normally held at substantial negative bias, with respect to the cathode, whereby the tube 39 normally remains non-conducting so that no current may flow in its plate circuit through the coil 38. A condenser 392 may be connected between the control grid 391 and the cathode of the thyratron tube 39 in order to absorb and thus eliminate the effect of voltage surges which otherwise might appear on the control grid 391 in response to the adjustment of the voltage selector switch 25. The tube may be triggered or fired to render it conducting, by reducing the negative bias on the grid to the triggering voltage level, after which current may flow through the coil 38 and cause it to open the switch 32 and simultaneously to close switch 36, thus disabling the power supply means to the tube 11 and energizing the warning device 37. After thus becoming conductive, the tube 39 will continue in such condition, even after high negative bias on the grid is restored, unless the plate circuit of the tube is interrupted momentarily. This may be accomplished by opening the reset switch 40, for a moment, and then reclosing it.

Power for operating the protective system may comprise a transformer 43 having a primary winding 44 connected between the taps 27 and 28 of the auto transformer. The transformer 43 has a secondary winding 45 connected in series with the switch 36 and alarm device 37 to energize the same upon closure of the switch 36. The transformer winding 45 also may be connected to energize the cathode of the thyratron tube 39, preferably through a resistor 46. The transformer 43 also has a secondary winding 47 having a center tap 48 and interconnected with a preferably electronic rectifier tube 49. The tube 49 has a cathode, and plate means, said plate means being connected with the opposite sides of the transformer winding 47 for full wave rectification between the tap 48 and the cathode. The transformer 43 may have a separate secondary winding 50 for energizing the cathode of the rectifier. A choke filter 51 and a capacitor 51' may be connected, as shown, in the output side of the rectifier, between the tap 48 and the cathode of the rectifier tube 49; and a resistor 52 and voltage regulating tube 52' may also be connected in the rectifier output to provide a constant, rectified output voltage.

Means is provided for variably biasing the grid of the tube 39 in accordance with the time, cathode excitation, and anode-cathode voltage adjustments of the X-ray apparatus, so that the thyratron will remain non-conducting, so long as such adjustments are within safe limits, but will become conducting as soon as the same become unsafe. To this end, the equipment for automatically adjusting the bias on the grid of the thyratron tube 39 may comprise a special tapered resistance 53 coupled mechanically with the synchronous timer 34 and adapted to be adjusted in accordance with the interval selecting adjustment of the timer. A similar tapered resistance 53' may be operatively associated and mechanically connected, in like fashion, with the impulse timer 34'. A switching relay 54 is provided for connecting the resistance elements 53 and 53' selectively in circuit with the output side of the rectifier and with the grid of the thyratron tube 39, in accordance with the timer selecting adjustment of the switch 29.

In this connection, the relay 54 comprises a pair of normally open switches 55 and 56 and a pair of normally closed switches 55' and 56', and a switch operating coil 57 adapted, when energized, to close the switches 55 and 56 and to open switches 55' and 56'. The resistors 53 and 53' are arranged as potentiometers having each a side connected, respectively, through adjustable resistance means 58 and 58', with the cathode of the thyratron tube 39, and thence through the resistor 41 and power source 42, to one side of the rectifier output. The other sides of the potentiometer resistors 53 and 53' are connected, respectively, with the switches 56 and 56', and thence to the other side 48 of the rectifier output.

The adjustable members of the tapered potentiometer resistors 53 and 53' may be respectively connected with the relay switches 55 and 55' and thence with the grid of the thyratron tube 39, through resistors 59 and 60. The coil 57 is connected in circuit between the auto transformer taps 27 and 28 through a switch adapted to close when the switch 29 is in its synchronous timer selecting position. Accordingly, the coil 57 will be connected between the auto transformer taps 27 and 28, and so energized, only when the switch 29 is in adjusted position to select the synchronous timer 34 for operation. At all other times the coil will remain de-energized. When the coil 57 is energized, only the tapered resistor 53 will be operatively connected with the rectifier output and the control grid of the thyratron tube 39 by closure of the normally open switches 55 and 56. Conversely, as long as the coil 57 remains de-energized, only the tapered resistor 53' will be operatively connected. Thus, the relay 54 serves automatically to connect the potentiometers 53 and 53' for bias control of the tube 39 as the switch 29 is in position selecting timer 34 or 34' for operation.

It will be seen that the adjusted position of the movable member of the resistor 53 or 53', when operatively connected with the tube 39 and the rectifier 49, will determine the amount of negative bias applied to the grid of the thyratron tube 39, such bias becoming progressively less negative and approaching the firing point of the thyratron tube as the mechanically connected and associated timer mechanism is adjusted toward its longer time settings, whereby the tube may be caused to fire and operate the protective relay if the time setting is made for a dangerously extended interval.

Conventional means, such as the filament transformer 16', the tapped autoformer 17', and the adjustable selector switch 18', may be provided for energizing the cathode 13 of the X-ray generator tube 11 at any selected one of a number of cathode excitation levels determined by the setting of the switch 18'; and means is provided for varying the bias on the grid of the thyratron tube in accordance with the adjustment of the excitation of the cathode of the X-ray tube in accordance with the setting of the switch 18', as well as the anode-cathode voltage adjustment accomplished by means of the switch 25. To this end, a plurality of potentiometers 61 may be provided to correspond, respectively, with the several cathode excitation settings at which the X-ray tube may be selectively adjusted. In this connection, the X-ray tube control equipment commonly includes cathode excitation control means operated by selector buttons, whereby the equipment may be conditioned to apply any desired cathode excitation to the X-ray tube by pushing the appropriate selector button on the control panel of the apparatus, selector clearing means being provided to retract any previously pressed button to inoperative position when a selected button is pushed.

The potentiometers 61 comprise resistance elements connected in parallel relationship between the auto transformer taps 23 and 25, and hence are energized at all times at a potential proportional to the operating potential applied between the anode and cathode of the X-ray tube. Each potentiometer 61 has an adjustable member connected through a corresponding, normally open switch 62 with the grid of the thyratron tube, through a capacitor 63 and preferably through the resistor 60. The switches 62 are each connected with a corresponding X-ray tube cathode excitation selector button. Accordingly, when

the X-ray tube apparatus is conditioned to provide cathode excitation at a selected intensity, the potentiometer 61 corresponding with the selected degree of cathode excitation will be connected with the grid of the thyratron tube. Each potentiometer 61, of course, may be individually adjusted by means of its adjustable element to apply grid bias on the tube in accordance with the degree of X-ray tube cathode excitation which it represents.

The basic negative bias applied to the grid of the thyratron through the potentiometers 53 or 53', as a function of the time setting, will thus be modified by a positive bias component supplied through a potentiometer selected from the potentiometers 61, said component being a proportional function not only of the anode-cathode potential at which the X-ray tube control apparatus is adjusted to operate, but also of the selected cathode excitation setting. The apparatus is arranged so that the positive bias component increases with increased anode-cathode voltage, and also increases with increased cathode excitation. Accordingly, the protective system may be adjusted to fire the thyratron tube 39 and disable the X-ray tube power supply system whenever the combined time, anode-cathode voltage and cathode excitation settings of the X-ray tube energizing equipment are such as would result in dangerously overloading the X-ray tube should it be operated under such set conditions.

The potentiometers 53 and 53' are adapted to apply a maximum negative bias to the grid of the tube 39, when the timers are set to their shortest interval timing adjustments. Such bias may be adjusted by means of the rheostats 58 and 58'. As a timer 34 or 34' is adjusted or set to longer X-ray exposure intervals, the corresponding adjustment of the potentiometer 53 or 53' will proportionally reduce the amount of negative bias on the grid of the tube 39. Since the potentiometers 61 are connected between the auto transformer taps 23 and 25, the bias component supplied to the grid of the tube 39, through the selected potentiometer 61, will be of positive character, during positive half cycles of energy supplied from the source 19, and will be proportional to the X-ray tube anode-cathode voltage, as determined by the adjustment of the tap 25. The bias component supplied through the selected potentiometer 61 will also be proportional to the selected X-ray tube cathode excitation, because of pre-set adjustment of the selected potentiometer. Since the bias component supplied through the selected potentiometer 61 is positive during alternate half cycles of energy supplied from the source 19, it will make the resultant bias, upon the grid of the tube, less negative during the intervals of such alternate half cycles. In the event that the resultant bias should reach the critical tube-firing value, during such alternate half cycle intervals, because of the adjustment of the timer to a dangerously long exposure interval, in view of the anode-cathode voltage and cathode excitation adjustments, the tube 39 will become conductive, and the relay 33 will operate to prevent the supply of operating power to the X-ray tube.

The system thus operates to apply a basic bias to hold the tube 39 normally inactive; to adjust the bias toward tube activating conditions as the timer is adjusted to longer time settings, and to further modify the bias toward tube activating condition in proportion to higher anode-cathode voltage and cathode excitation adjustments for the operation of the X-ray tube.

The capacitor 63 functions as a direct current blocking condenser and as a coupling capacitor to apply alternating voltage from the selected potentiometer 61 to the grid biasing circuit.

If desired, a normally closed disabling switch 64 may be connected in the energizing circuit of the relay switch coil 57. This switch 64 may be mechanically coupled and interlocked with one or more of the switches 62 so that the switch 64 will open and remain open so long as the switch or switches 62, with which it is connected, are in closed position. This will prevent the equipment from being operated under synchronous timer control, at cathode excitation levels corresponding with those of the switches 62, which are thus interlocked with the disconnect switch 64.

It is thought that the invention and its numerous attendant advantages will be fully understood from the foregoing description, and it is obvious that numerous changes may be made in the form, construction and arrangement of the several parts without departing from the spirit or scope of the invention, or sacrificing any of its attendant advantages, the form herein disclosed being a preferred embodiment for the purpose of illustrating the invention.

The invention is hereby claimed as follows:

1. A system for delivering power to an electron flow device, such as an X-ray tube, wherein heat generation is a function of several adjustable variables, including anode-cathode potential, cathode excitation and elapsed time of operating energy supply to the device, comprising a relay switch connected to control the supply of operating energy to said device, an electron trigger valve having a control grid and adapted for operation at a predetermined grid bias level and connected to control said relay switch, means for variably biasing the control grid of said valve in accordance with the adjustment of one of said adjustable variables, and means for modifying said bias in accordance with the adjustment of said other adjustable variable.

2. A system for delivering power to an electron flow device, such as an X-ray tube, wherein heat generation is a function of several adjustable variables, including anode-cathode potential, cathode excitation and elapsed time of operating energy supply to the device, comprising a relay switch connected to control the supply of operating energy to said device, an electron trigger valve have a control grid and adapted for operation at a predetermined grid bias level and connected to control said relay switch, means for variably biasing the control grid of said valve in accordance with the adjustment of said elapsed time variable, and means for modifying said bias in accordance with the adjustment of the anode-cathode potential and the cathode excitation level of said device.

3. A system for delivering power to an electron flow device, such as an X-ray tube, wherein heat generation is a function of several adjustable variables, including anode-cathode potential, cathode excitation and elapsed time of operating energy supply to the device, comprising a relay switch connected to control the supply of operating energy to said device, an electron trigger valve having a control grid and adapted for operation at a predetermined grid bias level and connected to control said relay switch, means adjustable with said elapsed time variable to negatively bias the control grid of said valve increasingly below said triggering bias level as the elapsed time variable adjustment of the device is reduced, and means adjustable with the anode-cathode potential and cathode excitation variables for applying, on the grid of said valve, a bucking bias component of increasingly positive character as the anode-cathode potential and cathode excitation are increased.

4. A system for delivering power to an electron flow device, such as an X-ray tube, wherein heat generation is a function of several adjustable variables, including anode-cathode potential, cathode excitation and elapsed time of operating energy supply to the device, comprising a relay switch connected to control the supply of operating energy to said device, an electron trigger valve, adapted for operation at a predetermined negative bias level and connected to control said relay switch, a potentiometer adjustable with the elapsed operating time adjustment of the device to negatively bias said valve increasingly below said triggering bias level as the elapsed time variable adjustment of the device is reduced, and potentiometer means energized in proportion to the anode-cathode potential adjustment and adjustable in accord-

ance with the cathode excitation adjustment of the device, for applying a bucking bias component, on said valve, of increasing positive character as the anode-cathode potential and cathode excitation are increased.

5. A system for delivering power to an electron flow device, such as an X-ray tube, wherein heat generation is a function of several adjustable variables, including anode-cathode potential, cathode excitation and elapsed time of operating energy supply to the device, comprising a relay switch connected to control the supply of operating energy to said device, an electron trigger valve, adapted for operation at a predetermined negative bias level and connected to control said relay switch, a potentiometer adjustable with the elapsed operating time adjustment of the device to negatively bias said valve increasingly below said triggering bias level as the elapsed time variable adjustment of the device is reduced, and a plurality of potentiometers all energized in proportion to the anode-cathode potential adjustment, and each adjustable in accordance with a corresponding one of a number of cathode excitation levels to which the device may be selectively adjusted, for applying a bucking bias component, on said valve, of increasing positive character as the anode-cathode potential and cathode excitation are increased.

6. A system for delivering power to an electron flow device, such as an X-ray tube, wherein heat generation is a function of several adjustable variables, including anode-cathode potential, cathode excitation and elapsed time of operating energy supply to the device, comprising a relay switch connected to control the supply of operating energy to said device, an electron trigger valve, adapted for operation at a predetermined negative bias level and connected to control said relay switch, a potentiometer adjustable with the elapsed operating time adjustment of the device to negatively bias said valve increasingly below said triggering bias level as the elapsed time variable adjustment of the device is reduced, and a plurality of potentiometers all enerigized in proportion to the anode-cathode potential adjustment, and each adjustable in accordance with a corresponding one of a number of cathode excitation levels to which the device may be selectively adjusted, for applying a bucking bias component, on said valve, of increasing positive character as the anode-cathode potential and cathode excitation are increased, and interlocking switch means, operable upon adjustment of the device for operation at one of said cathode excitation levels for preventing the delivery of operating power to said device.

7. The combination, with an X-ray tube having an anode and an electron emitting cathode, of relay switch means for controlling the delivery of operating power between said anode and cathode, adjustable means for varying the anode-cathode potential at which said power is to be delivered, adjustable means for exciting the cathode for electron emission, at various intensity levels, adjustable timer means for determining the elapsed time interval during which operating power may be delivered to the tube, an electron trigger valve having a control grid and adapted for operation at a predetermined grid bias level and controllingly connected with said relay switch means, means for variably biasing the control grid of said valve, in accordance with adjustment of one of said adjustable means, and means for modifying said bias in accordance with the adjustment of said other adjustable means.

8. The combination, with an X-ray tube having an anode and an electron emitting cathode, of relay switch means for controlling the delivery of operating power between said anode and cathode, adjustable means for varying the anode-cathode potential at which said power is to be delivered, adjustable means for exciting the cathode for electron emission, at various intensity levels, adjustable timer means for determining the elapsed time interval during which operating power may be delivered to the tube, an electron trigger valve adapted for operation at a predetermined bias level and controllingly connected with said relay switch means, means adjustable with said timer means to negatively bias said valve increasingly below said triggering bias level as said timer means is adjusted progressively for shorter elapsed time operation, and means operable in accordance with said anode-cathode potential adjustment, and in accordance with said adjustment of cathode excitation, to apply, on said valve, a bucking bias component of increasingly positive character in proportion to increase in adjusted anode-cathode potential and cathode excitation intensity.

9. The combination, with an electrical load device, in which the generation of heat is a function of load current, load voltage and the elapsed time during which electrical power is applied to the load device, of relay switch means for controlling power delivery to said load adjustable means for varying load voltage, adjustable means for varying load current, adjustable timer means for determining the time interval during which operating power may be supplied to said load device, an electron trigger valve having a control grid and adapted for operation at a predetermined grid bias level and controlling connected with said relay switch means, means adjustable with said timer means to negatively bias the grid of said valve increasingly below its triggering bias level as said timer means is adjusted progressively for shorter elapsed time operation, and means operable in accordance with the adjustment of load voltage and of load current to apply, on the grid of said valve, a bucking bias component of increasingly positive character in proportion to increase in adjusted load voltage and current.

10. A system for delivering power to a heat generating electrical load in which the generation of heat is a function of several adjustable variables, including load voltage, load current and the elapsed time interval during which electrical power is applied to the load, comprising a relay switch connected to control the supply of power to said load, an electron trigger valve having a control grid and adapted for operation at a predetermined grid bias level and connected to control said relay switch, means for applying a bias on the grid of said valve varying in accordance with the adjustment of said elapsed time variable, and means for modifying said bias in accordance with the adjustment of load voltage and current.

11. A system for delivering power to a heat generating electrical load in which the generation of heat is a function of a plurality of adjustable variables, comprising a circuit for supplying power to said load, a relay switch in said circuit for controlling the flow of operating power to said load, an electron trigger valve having a control grid and adapted for operation at a predetermined grid bias level and connected with said switch to operate the same, means comprising a potentiometer, adjustable in accordance with the adjustment of one of said adjustable variables, to correspondingly bias the grid of said valve, and bias modifying means, adjustable in accordance with the adjustment of another of said variables, to correspondingly modify the bias on said grid.

12. A system for delivering power to a heat generating electrical load in which the generation of heat is a function of a plurality of adjustable variables, comprising a circuit for supplying power to said load, a relay switch in said circuit for controlling the flow of operating power to said load, an electron trigger valve having a control grid and adapted for operation at a predetermined grid bias level and connected with said switch to operate the same, means comprising a potentiometer energized at a voltage varying in accordance with the adjustment of one of said adjustable variables, to correspondingly bias the grid of said valve, and means to adjust said potentiometer in accordance with the adjustment of another of said variables, whereby to apply a composite bias on said grid adjusted in accordance with the adjustment of both of said variables.

13. A system for delivering power to a heat generating electrical load in which the generation of heat is a function of plurality of adjustable variables, comprising an electron trigger valve having a control grid and adapted for operation at a predetermined grid bias level and connected to control the flow of operating power to said load, means for applying a control bias on the grid of said valve varying in accordance with the adjustment of one of said adjustable variables, and means for modifying said bias in accordance with the adjustment of another of said variables.

14. A system for delivering power to a heat generating electrical device in which the generation of heat is a function of a plurality of variably adjustable operating conditions including duration of operating time interval and operating voltage at which power may be delivered, which conditions may be selectively determined and adjusted prior to the placement of the device in operation, comprising a normally closed switch for controlling the delivery of power to said device, a normally open switch closable to set the device in operation under selected operating conditions, an electron trigger valve having a control grid and adapted for operation at a predetermined grid bias level to open said normally closed switch, means for applying a control bias of predetermined value on the grid of said valve to hold the same normally inoperative, means operable to alter said bias in accordance with the adjustment of one of said adjustably variable conditions, and means for modifying said bias in accordance with the adjustment of another of said adjustably variable conditions, whereby said valve may be actuated to open said normally closed switch to thereby prevent delivery of power to said device in response to the closure of said normally open switch when said selected operating conditions are such that the device would be electrically overloaded if operated under such selected variable conditions.

15. A system for delivering power to an electron flow device, such as an X-ray tube, wherein heat generation is a function of several adjustably variable operating conditions, including anode-cathode potential, cathode excitation level, and duration of operating time interval, which conditions may be selectively determined and adjusted prior to the placement of the device in operation, comprising a normally closed relay switch for controlling the delivery of power to said device, a normally open switch closable to set the device in operation under selected operating conditions, an electron trigger valve having a control grid and adapted for operation at a predetermined grid bias level to open said normally closed switch, means for applying a control bias of predetermined value on the grid of said valve to hold the same normally inoperative, means operable to alter said bias in accordance with the adjustment of the operating time interval, and means for modifying said bias in accordance with the selected anode-cathode potential and also in accordance with the selected cathode excitation level, whereby said valve may be actuated to open said normally closed switch to thereby prevent the delivery of power to said device in response to the closure of said normally open switch when said selected values of operating potential, cathode excitation, and duration of operating time interval are such that the device would be electrically overloaded if operated under such preselected operating conditions.

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