The invention relates to high voltage rectifiers, more especially thermionic rectifiers such as are utilized in connection with the operation of cathode ray tubes, luminous or fluorescent tubes, X-ray apparatus, and similar devices utilizing voltages and currents of such magnitude as normally to be considered dangerous. These voltages constitute a hazard not only for those who may be required to service the apparatus, but also in some instances to those operating the same.

It has heretofore been the practice to employ rectifiers for such high voltages with but a single terminal for the anode and another for the cathode. Consequently, if either were contacted by the human body while a dangerous power was on, a severe if not fatal shock was received through the body when the circuit was completed to ground or to the return lead of the supply source.

In my U.S. Patent Nos. 2,281,571 and 2,281,572 and my application for U.S. Letters Patent Serial No. 517,336, filed January 7, 1944, I have shown how sources of dangerous voltages, such as transformer and condenser circuits, may be made safe to handle. In the various systems disclosed therein a plurality of rectifiers is employed when the current required to operate the apparatus is more than can be safely contacted. By dividing the dangerous current into a number of separate paths, with individual rectifiers in each path, the circuit paths are made safe by limiting the amount of current passing through each path to a safe value by the insertion of resistors in these paths. The resistance value of such resistors is always to be sufficiently low for the operation of the apparatus when all the paths are combined. Contacting any single path by the body results in receiving only the limited or safe current in that path, which is the result of a drop of voltage in the circuit path to a harmless value when contacted. Because of the asymmetric properties of the rectifiers, the currents in the uncontacted circuit portions are prevented from combining and returning through the body.

An object of the present invention is to combine the circuit paths in a single rectifier element instead of employing a separate rectifier for each path. By this means the cost of the apparatus is greatly reduced and the entire system greatly simplified.

A further object is to provide a novel combined socket and junction box for the rectifier.

A still further object is to provide an external cap for the rectifier anode connections and/or base connections in which cap are located protective resistors, only safe terminals of the rectifier element or elements being exposed; also, to enclose such protective resistors within the rectifier envelope itself.

Another object of the Invention is to provide a safety cable for connections to and from the rectifier.

Still another object is to provide a high potential power supply in which the wiring of the various high potential apparatus is confined in a protective casing.

Other auxiliary objects will hereinafter appear.

In the operation of the apparatus, the novel rectifier including socket terminals, anode and cathode protective resistors, and rectifier filament heating transformer are designed to be confined in a metal housing or junction box preferably grounded, or they may be located in a heavily insulated housing of plastic or some such material, with outlets in the junction box for the connections of a novel safety cable.

Alternatively, the anode and cathode protective resistors may be located in a glass, plastic, or other insulated housing fused or cemented to the top and/or bottom of the rectifier, or mounted within the rectifier itself.

The nature of the invention, however, will best be understood when described in connection with the accompanying drawings, in which:

Fig. 1 is a diagrammatic view illustrating the circuit connections and arrangement of the novel rectifier unit with relation to other units of a safety high-voltage power supply for operation of a cathode ray tube.

Fig. 2 is a plan view of the novel rectifier unit as installed between a safety high-voltage transformer unit and a safety high-voltage condenser unit, with safety cables between these latter and the rectifier junction box, the rectifier power unit energizing the elements of a cathode ray tube through said condenser unit.

Fig. 3 is a cross-section, on an enlarged scale, of the novel safety concentric cable for connecting the rectifier unit with other power units.

Fig. 4 is an enlarged longitudinal section, partly in elevation, of a safety cable terminal with jacks receiving corresponding prongs.

Fig. 5 is a fragmentary view, in part section, illustrating an alternative form of connecting cables.

Fig. 6 is a view in elevation of one form of rectifier suited to the novel rectifier unit; and Fig. 7 is a bottom view thereof showing its connecting prongs.

Fig. 8 is a front elevation and part longitudinal
section of an alternative form of rectifier having a special safety anode cap.

Fig. 9 is a similar view illustrating a modification.

Fig. 10 is a bottom view, and Fig. 11 is a vertical section of the safety socket for receiving the base prongs of the form of rectifier shown in Fig. 8.

Referring to the drawings, more particularly to Fig. 1, 16 designates a casing or housing which may be, if desired, a metal grounded at 14, and is provided with an inlet preferably in the form of a suitable connecting plug (indicated in Fig. 2) which, in turn, is connected to a source of power. This source may, for convenience, be 110-volt, 60-cycle alternating current, as indicated at 12, and energizes the primary 13 of a high-voltage transformer, of the magnetic leakage type, if desired, and having also a core 14 and high potential secondary 15. One terminal of the secondary of this transformer is grounded, preferably through a plurality of branches each provided with a protective resistor 11. The lead from the other terminal is divided into a plurality of branches, in the present instance four, each with protective resistors 16, 17, 18, and 19 connecting externally of the casing 10 with test terminals 21, 22, and 23, respectively, which latter may also serve for connections to a rectifier unit as hereinafter set forth, or they may be extensions of a cable socket terminal.

Additional terminals 24 and 25 are provided exteriorly of the casing for power leads connected to the 110-volt supply line and running from the transformer casing as the leads 26, 27 along with the high voltage leads 28, 29, 30, and 31, to the rectifier junction box 32 which may be of metal and grounded at 33.

The rectifier socket 34 in said junction box contains protective resistors 35, 36, 37, and 38 which are confined therein in series with the respective anode branch leads 28, 29, 30, and 31 connected to respective jacks 39, 40, 41, and 42 of the socket.

Pin jacks 43 and 44 are also provided in the socket for the cathode ray tube connections for the rectifier cathode, while 45, 46, 47, and 48 designate the cathode ray tube pin jacks of said socket which are connected with protective resistors 49, 50, 51, and 52 inserted in series in the leads 53, 54, 55, and 56 from the said respective pin jacks 45, 46, 47, and 48. Leads 57 and 58 are connected to the output of the low-voltage transformer 59 for energizing the heater of the cathode of the cathode ray tube, the transformer and conductors being placed for safety purposes. The secondary being adapted for connection to the rectifier filament terminals through the pin jacks 43 and 44.

Test terminals for the input leads 53, 54, 55, and 56, respectively, to the safety condenser box 61 are located exteriorly thereof as at 62, 63, 64, and 65, and protective resistors 66, 67, 68, and 69 are provided in the input leads between these terminals and the safety filter condenser unit comprising condensers 70 and 71 also housed in the metal casing or box 61 which is grounded at 72. A filter resistor 73 and protective resistor 74 for test terminals 75 and 76 are connected with said condensers, while protective resistors 77, 78, 79, and 80 are provided in the corresponding output branches of the filter condenser unit, as set forth in my aforesaid pending application Serial No. 517,336.

Test terminals 81, 82, 83, and 84 are provided for the output leads of the safety condenser unit, 75 and test terminals 85 and 86 for the cathode ray tube heater leads are similarly provided exteriorly of the box 61.

The cathode 87 of the cathode ray tube 88, which is energized from the condenser unit, has a negatively biased control grid 89 with video amplifier terminal 90, and is associated with a first anode 90, having a voltage control potentiometer 92, and with a second anode 93. The respective horizontal and vertical deflection grids 82 and 83 of the tube are connected with the signal input leads 84, 85 and 95, 96 which are preferably of the shielded type.

The novel safety cable structure is shown in Fig. 3, 92 Indicating the grounded outer tubular sheathing or armor of the safety cable which sheathing, as well as the shielded conductors, may be of flexible woven-wire tubing. A layer of suitable insulation 99 is included between the outside sheathing 88 and the next concentric conductor tubing 100 which may, for example, be one of the rectifier tube, high-potential anode leads such as the lead 28, Fig. 1. A further layer of insulation 101, such as varnished cambric, is interposed between this conductor and the next concentric conducting sheathing 102 which may be a slightly smaller flexible woven-wire tubing provided at one end. The next tubing of insulation 103 is included between the grounded sheathing 102 and the next conductor 104 which may be another of the rectifier anode leads as the lead 29, Fig. 1.

The remaining rectifier anode leads 20 and 31 may be located similarly and concentrically with intermediate insulation and grounded sheathing, the final and central core conductor being rectifier anode lead 31.

If desired, the rectifier heater transformer leads 26, 27, Fig. 1, may also be included in the same cable, with additional insulation between them and the other leads, as is well understood. The connections between the rectifier cathode and the safety condenser and the connections between the safety condenser and the cathode ray tube may be made up into a similar safety cable, terminating in connecting plugs or jacks, as indicated in Fig. 2 and hereinafter more fully set forth.

An alternative arrangement, Fig. 5, shows a variation in the manner of inserting the protected grounded sheathing between any two live conductors and consists in providing a single conductor and grounded sheath cable, as shown at 105, for each of the rectifier anode leads instead of laying the conductors one inside the other. For example, cables for the leads 28, 29, 30, and 31, Fig. 1, and similar cables for the heater transformer leads 26, 27, if desired, are laid side by side. These single cables may then be grouped in a single twisted cable or they may be laid parallel, as shown. The main requirement is that a grounded sheath 105 shall surround each conductor suitably insulated therefrom when the cable is used for high power. For low power, the interposed grounded sheathing may be omitted if desired, and only the usual insulation interposed between the high voltage conductors.

The reason for using the grounded sheathing in high power cables is that, in case of a breakdown of insulation and a consequent destruction of this insulation with possible fusing of conductors, there will always be a grounded conductor between any two live conductors, so that should accidental contact by the body with a broken-down cable occur, no harm will result
as the entire section of high potential cable will have been fused into a grounded conductor.

The high potential tubular conductors are heavily insulated by the concentric layers 96, 101 and 103 of some such material as oiled muslin or plain muslin saturated with oil, in which case the cable is provided with an oil-tight jacket.

Any other live conductors, insulating tubings, and groundings of conductors of the cable may be similarly arranged in concentric form. It is to be understood that heavy insulation is required only between live conductors and grounded sheathing. As all high voltage conductors of a group are of the same potential, it is not necessary to provide any barrier or oil space between them when they are located close together as cable jack terminals.

The safety cable shown in Fig. 3 may be fanned out as its terminals as indicated in Fig. 4, and the terminal block or plug 108 with the cooperating prongs 107 may be of plastic or porcelain suitable for the voltage employed. This block may be mounted in a junction box 105 similar to the box 32, shown in Fig. 1, and is provided with a row of the pins or plugs 107. These are circularly disposed on the box and countersunk below the surface. It will be noted that one of these pins or plugs is preferably made longer than the others. This is to make it impossible to touch more than one pin at a time accidentally, and in case of contact with such longer pin, an instinc- tive warning is given to proceed cautiously.

The enclosure opening for the cable plug in such case is to be made smaller than the human finger. The cooperating cable terminal plug 108 may be constructed of insulating material such as plastic with countersunk jacks 107 and the sheaths of all cable leads entering the box are grounded as indicated. The cable connections may be either male or female, but it is preferred to have the terminals of the female type when exposed to contact with the body, as this type is less likely to present a plurality of exposed conductors which might be simultaneously contacted.

The general arrangement of the various apparatus hereinbefore described is indicated in Fig. 2 wherein 110 indicates the exterior of a cathode ray housing which may, for example, be of metal grounded at 111 and is provided with an inlet for a plug 112 with leads for introducing the power from a 110-volt alternating current source of supply. Test terminals 115 are provided on the outside of the casing and may be of the usual pin-jack variety, without inserted protective resistance since the supply voltage is not dangerous. Similar test terminals 24, 25, and 20, 21, 22, 23 for the power leads and for anode leads may also be provided. At 116 is shown the cable plug connection of the safety cable 117, which is grounded, and 118 the cable plug connection to the rectifier junction box 119 which may also be of metal, grounded at 120. Box 119 is provided with a socket 121 of insulating material such as porcelain or plastic and preferably, of the wafer-type with four socket terminals for connection to the rectifier anode and four socket terminals for connection to the rectifier cathode. Rectifier heater socket terminals or pin jacks 124 are also included in the socket 121.

An outlet plug 125 of the rectifier junction box is connected to the grounded safety cable 126, which carries an inlet plug 127 for connection to the safety condenser unit housed, for example, in a metal box or casing 128 grounded at 129. This casing has four test terminals 130 which, for convenience, may be countersunk in the outer surface of the casing, for example at the top.

Test terminals 131 of the safety filter condenser and test terminals 132 of the cathode ray tube heater supply may, for convenience, and by corresponding leads run through the condenser casing, be provided on the top of said casing in order to simplify cable test connections thereto. Test terminals 133 to the branch circuits from the various output protective resistors of the condenser also are provided on the top of said casing. A grounded outlet plug connects 134 with grounded safety cable 135 connects through a plug 136 the condenser power unit to the cathode ray tube socket terminal box 137, which may be of plastic, for example. The cathode ray tube 138 may be as such might be used, for example, in a television set, 139 designating the control grid lead to the video amplifier (not shown), while 140, 141 designate the horizontal deflector terminals and 142, 143 the vertical deflector terminals or leads, all of which latter are preferably flexible and need not be heavily insulated since, by the arrangement of circuits hereinbefore described, they are safe to touch.

A suitable rectifier for use in the rectifying unit is shown in Fig. 6, wherein 150 designates the glass envelope of a low-power, high-voltage rectifier having the cathode 151, the anode 152, the heater 153, a plurality of anode pins 154, a plurality of cathode pins 155, and the two heater pins 156. The number of anode and cathode pins conforms to the number of branch circuits associated therewith, and as indicated more particularly in Fig. 7, the four anode pins 154 are connected together, and likewise the four cathode pins 155. The independently connected heater pins 156 are located between said groups of cathode and anode pins. Such rectifier is therefore adapted for use in the socket 34, Fig. 1, and since no bodily contact is possible with the cooperating jacks when the rectifier is positioned in the said socket, the rectifier circuits are perfectly safe. Withdrawing the rectifier interrupts the power connection to said rectifier, and as the branch circuits of the socket terminals are each equipped with the protective resistors, the jacks are individually safe to contact.

Another form of rectifier is illustrated in Fig. 8, wherein 161 designates the glass envelope of a high-voltage, high-power rectifier having the anode 162, cathode 163, and heater 164. In the insulation base are provided two heater pins 165 and a plurality of cathode pins 166, in the embodiment shown, four, for effecting connection with suitable sources of power, all of the said cathode pins being electrically interconnected within the said base of the rectifier.

In this embodiment, the cathode and anode pins are mounted respectively at opposite ends of the envelope, and in accordance with the invention, protective resistors 167, 168, 169 and 170 for the anode are included inside a hollow anode cap 171, mounted on top of the envelope 161, said resistors being located in branch circuits from the anode lead 172 to the respective cap pins 173, 174, 175, and 176. The cathode pins 166, as well as the heater pins 165, are designed to fit a special form of socket 178, Figs. 10 and 11, of insulation material, having the jacks 181 to receive the former and 182 to receive the latter pins. Protective resistors 183 are included in leads to the respective jacks 181 and are located in said
base. By eliminating the resistors in the connections from jacks 181, a socket of this type is suitable for effecting external connection at the top of the rectifier.

In Fig. 9, a similar pin arrangement is indicated, the same being supported by a hollow socket 189 of plastic or porcelain, there being four cathode pins 191 affixed thereto, together with two heater pins 192. The respective protective resistors 193, however, are in this instance mounted inside the envelope 194 of the rectifier and the leads united therein to form a common lead 195 which is connected to the cathode 196. Similarly, the plurality of anode resistors 200 are located within and united for connection to the anode 201 within the envelope 194, being connected to respective pins 202 retained by an insulating cap 203. Over these pins may be fitted a connecting plug 204 bearing the jacks 205 from which extend the branch leads 206.

In the latter embodiment, wherein the cathode resistors are contained within the rectifier envelope, it will, of course, be appreciated that no socket or resistors need be provided in the socket member adapted to receive the said cathode pins of the rectifier.

The various sockets for receiving the different types of rectifiers may be mounted on the outside of the casing such as that shown at 118, Fig. 2, with the filament or heater transformer for a rectifier also housed in the casing. Unless the heater transformer is thus enclosed or protected, it may be subject to a breakdown between the cathode element and the heater element especially in the case of very high voltage rectifiers, thereby making the heater transformer unsafe to touch. It is therefore preferable to leave exposed only the socket terminals of the rectifier cathode with protective resistors in series.

As an example of the resistance values of, say, four cathode protective resistors, there may be of the order of 120,000 ohms each when the transformer voltage is approximately 3,000 volts. The four protective resistors in the rectifier anode may likewise be of the same value. This places all of the four cathode or anode resistors in parallel, making a total resistance of 30,000 ohms in the cathode lead. Since the anode and cathode resistors are in series parallel, a total resistance of 60,000 ohms plus the resistance of the rectifier itself, is located between the transformer output terminals 20, 21, 22, and 23 and the condenser input terminals 62, 63, 64, and 65.

The transformer protective resistors 16, 17, 18, and 19, Fig. 1, of like resistivity, should have a total resistance value preferably less than that of the resistors of the rectifier, and the condenser protective resistors 66, 67, 68, and 69 should have a total resistance value greater than that of the resistors of the rectifier.

As examples of the resistance values of the transformer protective resistors 16, 17, 18, and 19, these may be 50,000 ohms each, which is less than the resistance of the rectifier resistors; and the condenser resistors 66, 67, 68, and 69 may be 160,000 ohms, which is greater than the resistance of the rectifier resistors. Thus, each transformer resistor permits a maximum current of only 3.75 milliamperes to flow, while each rectifier resistor permits a maximum of but 2.5 milliamperes, and each condenser resistor but 1.25 milliamperes to flow.

In other words, the protective resistance values of the system should increase progressively from the high voltage source to the cathode ray tube terminals. A convenient rule to follow in designing the protective resistors to avoid draining the filter system is to increase progressively the total resistance value of each set of parallel resistors, starting with the transformer output and terminating at the filter condenser output, the number of resistors in parallel being the same for each set of resistors. Alternatively, the rule may be to decrease progressively the number of resistors of each set in parallel, all individual resistors being of the same value.

The resistance value of each resistor is such that its exposed terminals, which should be countersunk deeply below the outer surface of the casing, may be safely and comfortably contacted singly, which is the usual accidental contact by the human body.

Under these same conditions, a total maximum current of 15 milliamperes may flow through the transformer resistors, 10 milliamperes through the rectifier resistors, and 7.5 milliamperes through the condenser resistors.

All these current values approximate the safety limit, and while they may not be considered dangerous, they are certain to produce no harmful effects. The only way that these currents could be drawn through the body, however, would be to contact all four resistor terminals simultaneously. As this would be considerable of a feat, it would not be done accidentally, and the safety feature becomes at once apparent.

In the first place, a test probe or some such instrument is needed, to make contact with any test terminal, as these are all deeply countersunk below the surface of the casing. Secondly, upon accidental contact with any single test terminal or lead, a "let go" warning is given in the nature of a mild shock which immediately and instinctively warns the person contacting a live terminal to proceed cautiously.

The parallel resistor value of the protective resistors should be sufficiently low to allow optimum operation of the apparatus, but the individual resistance of each protective resistor should be sufficiently high to produce a drop of voltage when contacted by the body to a value which is not only safe but comfortable to touch. It will be seen that any degree of safety can be obtained by simply increasing or decreasing the value of each individual protective resistor and increasing or decreasing the number of resistors in parallel in the input and output circuits of the units.

The type of rectifier shown in Fig. 6 is suitable for voltages up to 1,500 volts and because of its simplicity is to be recommended. However, enlarging the base diameter permits of using higher voltages.

It will be noted, reference being had to Figs. 6 and 7, that the base pins of the rectifier shown therein are divided into groups of four each for the anode and cathode, and two for the heater. The reason for this is to provide an additional safety feature for the socket 34, shown in Fig. 1. When the rectifier is inserted in the socket, neither the anode nor the cathode circuits can ordinarily be safely touched unless protective resistors have been included in the circuit. When the rectifier is removed, for example for testing purposes, the pin jacks 45, 46, 47, and 48 of the cathode, and pin jacks 39, 40, 41, and 42 of the anode, Fig. 1, are all completely separate, being made so by the removal of the connecting pins 15 and 154 of the tube base.

The high-power rectifier shown in Figs. 8 and 9.
is suitable for voltages of 1,500 to 10,000 and over. It is to be understood that the protective resistors in the glass or plastic anode cap, Fig. 9, and in the base and cap, Fig. 9, are not limited to four. Any number may be used depending upon the current required. The same holds true for the cathode resistors 183 in the socket member for the rectifier shown in Fig. 8.

It is desirable, but not necessary, that the number and resistance value of protective resistors of the anode should match those of the cathode.

The arrangement described herein of high-voltage rectifier unit with the safety transformer unit and arrestor combination, forms a compact and moisture-proof combination, particularly suited for the operation and testing of cathode ray apparatus, such as radar oscillographs, especially when used in damp or humid climates.

I claim:

1. In a thermionic rectifier for operation at nominally dangerous current and voltage values and including an envelope with a single anodic element and a single associated cathodic element mounted therein: a plurality of terminals for one of the elements, separate circuits connecting the respective terminals to said one of the elements, and enclosed current-limiting means connected between said one of the elements and the terminals and included in series with each of said separate circuits, said current-limiting means being of an order of magnitude sufficiently low to permit optimum operation of the rectifier at the rated voltage and sufficiently high, with respect to said voltage, such that upon establishment of a closed circuit between a terminal and the human body the flow of current therethrough will be limited to a harmless value due to the resultant voltage drop.

2. The thermionic rectifier of claim 1, wherein the element connected to the plurality of terminals is the anodic element.

3. The thermionic rectifier of claim 1, wherein the element connected to the plurality of terminals is the cathodic element.

4. The thermionic rectifier of claim 1, wherein respective groups of terminals and corresponding separate circuits, each with current-limiting means, are connected to the anodic element and to the cathodic element.

5. The thermionic rectifier of claim 1, wherein the current-limiting means are resistors.

6. The thermionic rectifier of claim 1, wherein the current-limiting means are resistors and all of the resistors are of substantially like resistivity.

7. A thermionic rectifier having a single anodic element and a single associated cathodic element, a plurality of terminals for one of the elements, and separate circuits connecting the respective terminals to said one of the elements, together with enclosed respective resistors connected between said one of the elements and the terminals and included in series with each of said separate circuits.

8. The thermionic rectifier of claim 1, wherein the terminal connections comprise a fixed portion and a portion secured to the rectifier, said portions being separable from each other, and the current-limiting means are located in series with the respective fixed portions of the terminal connections.

9. In a thermionic rectifier for operation at nominally dangerous current and voltage values and including an envelope with a single anodic element and a single associated cathodic element mounted therein, a plurality of terminals for one of the elements located exteriorly the said envelope, separate circuits connecting the respective terminals to said one of the elements and enclosed current-limiting means connected between said one of the elements and the terminals and included in series with each of said separate circuits, said current-limiting means being of an order of magnitude sufficiently low to permit optimum operation of the rectifier at the rated voltage and sufficiently high, with respect to said voltage, such that upon establishment of a closed circuit between a terminal and the human body the flow of current therethrough will be limited to a harmless value due to the resultant voltage drop.

10. The thermionic rectifier of claim 9, wherein the current-limiting means are located within the envelope.

11. The thermionic rectifier of claim 9, wherein the current-limiting means are located exteriorly of the envelope.

12. The thermionic rectifier of claim 9, wherein a hollow cap is provided over the envelope for supporting the terminals of said one of the elements and the current-limiting means are located within said cap.

13. A thermionic rectifier including an envelope with a single anode and a single associated cathode element mounted therein; a plurality of terminals supported at one end of the envelope connected with the anode, and a plurality of terminals supported at the opposite end of the envelope connected with the cathode, and casings for enclosing the respective sets of terminals.

14. The thermionic rectifier of claim 1, wherein separate circuits are connected to the other element of the rectifier and are similarly provided with current-limiting means, the two groups of said circuits of the rectifier being connected respectively with a source of high voltage and with a work circuit, the total parallel resistance value of the high voltage group of circuits being less than the parallel resistance value of the work group of circuits.

15. A thermionic rectifier unit, comprising a closed protective casing, a thermionic rectifier adapted to be mounted therein adapted for operation at nominally dangerous current and voltage values, said rectifier including an envelope with a single anodic element, a single associated cathodic element and a heater member mounted therein, a low voltage transformer mounted in the casing and adapted for connection with the rectifier heater member, a high voltage source of power including a plurality of separate circuits adapted for connection with one of the said rectifier elements, a terminal member mounted in the casing for affording connection externally thereof, said terminal member being connected to the said low voltage transformer and to said high voltage source of power, and including a plurality of high voltage terminals for one of the rectifier elements separately connected to said respective circuits of the high voltage source of power, and a low voltage terminal for the heater member connected to the low voltage transformer, all of said high voltage terminals being adapted for connection with one of the rectifier elements and the low voltage terminal to the heater member, and current-limiting means included within the casing between said one of the rectifier elements and the high voltage terminals and included in series with each of said high voltage separate circuits, said current-limiting means being of an
order of magnitude sufficiently low to permit optimum operation of the rectifier at the rated voltage and sufficiently high, with respect to said voltage, such that upon establishment of a closed circuit between a rectifier terminal and the human body the flow of current therethrough will be limited to a harmless value due to the resultant voltage drop.

16. The method of operating a thermionic rectifier from a source of alternating current of nominally dangerous voltage, said rectifier including a single anode element and a single cathode element, which comprises supplying the total energy from said source at a dangerous voltage to one of the elements by dividing it into a plurality of independent paths, restricting the current flow in each path to a safe value, recombining at said one element the individual currents of the respective paths to provide current of the desired operating value, distributing the energy from the other element of the rectifier by dividing at said other element the current into a plurality of independent useful paths, and restricting the individual currents in the respective useful paths to a safe value.

EDWARD G. GAGE.