Nov. 15, 1932. T. F. CHENEY 1,887,868

RECTIFIER

Filed Nov. 3, 1925

Fig. 1.

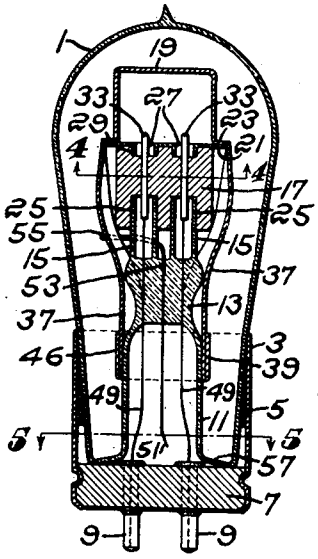


Fig. 2.

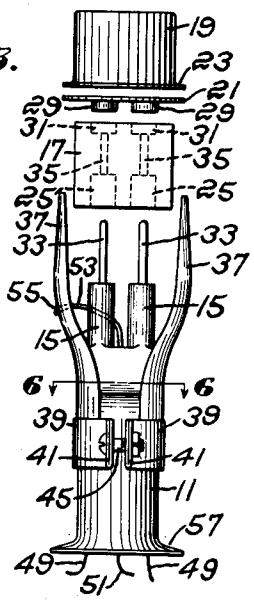


Fig. 3.

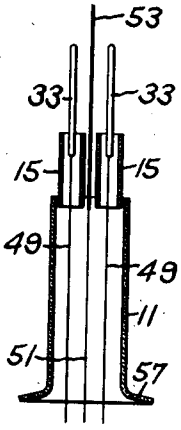


Fig. 4.

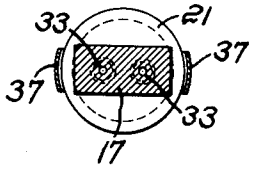


Fig. 7.

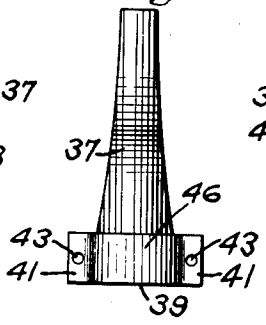


Fig. 6.

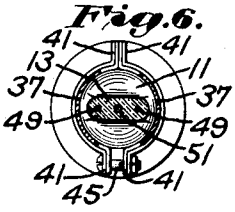


Fig. 5.

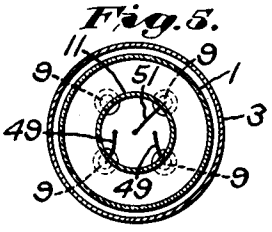
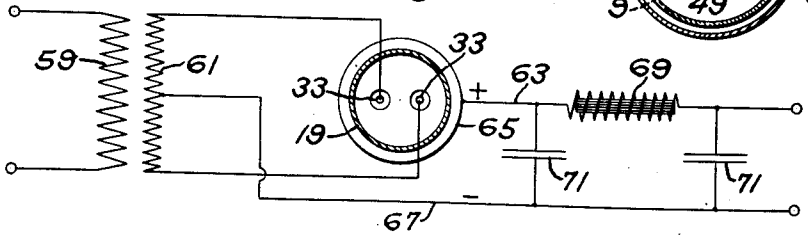


Fig. 8.



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UNITED STATES PATENT OFFICE

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RECTIFIER

Application filed November 3, 1925. Serial No. 66,627.

My invention pertains to rectifiers for alternating current, and particularly but not exclusively to a full-wave rectifier.

My invention will be best understood from the following description when read in the light of the accompanying drawing of one specific embodiment of my invention selected for illustrative purposes, while the scope of my invention will be more particularly pointed out in the appended claims.

In the drawing:—

Fig. 1 is a longitudinal section of a rectifier constructed according to my invention;

Figs. 2 and 3 show portions of the device in unassembled relation;

Figs. 4 and 5 are sections on the lines 4—4 and 5—5 of Fig. 1;

Fig. 6 is a section on the line 6—6 of Fig. 2;

Fig. 7 is a side elevation of the support at right angles to the support as viewed in Fig. 2; and

Fig. 8 is a schematic circuit diagram showing an application of a full-wave rectifier constructed according to my invention.

Referring to the drawing I have shown a rectifier which as illustrated comprises a container 1, preferably a glass bulb, which may be carried by a base comprising a sleeve 3 surrounding the lower end of the bulb and secured thereto in any suitable manner, as for example by means of bakelite cement indicated at 5. As illustrated the lower portion of the sleeve carries a disk 7 of insulating material, as for example porcelain, provided with four contact prongs 9 for adapting the base to common forms of sockets employed in connection with radio and like apparatus.

It will be understood by those skilled in the art that other forms of bases than that illustrated may be employed in connection with a rectifier constructed according to my invention, and that although I have illustrated a bulb with a tip my invention is equally as applicable to bulbs of the "tipless" type.

As illustrated the bulb interiorly carries an axially situated tubular stem 11, preferably formed of glass, and which opens to the exterior of the bulb at the end of the bulb received by the socket. The upper end of the tubular stem 11 is closed as is indicated at 13, and, as illustrated, formed integrally with the closed end of the stem is a pair of spaced tubes 15 of insulating material, preferably glass. On the upper end of the tubes 15 is shown a block 17 of insulating material, and upon the block 17 a hollow member comprising a cap portion 19, which preferably is cylindrical, and an end plate 21, the latter of which rests against the annular flange 23 at the lower end of the cylinder wall of the cap. As illustrated the block 17 is recessed at 25 for receiving the ends of the tubes 15, while the plate 21 is perforated as is indicated at 27 and provided with projecting annular walls 29 surrounding these perforations, the annular walls 29 being received in recesses 31 formed in the block 17 and alignment with the recesses 25, it being observed that by these means the block and plate 21 are held against lateral displacement relatively to each other and to the tubes 15.

The cap 19 and plate 21 are formed of conducting material impregnated or coated with electron emitting material, for example the cap and plate may be of steel pressed to the shape illustrated and coated with an oxide of a rare-earth. Preferably prior to the incorporation of the cap and plate into the finished device the inner surface of the cap and the upper side of the plate 21 together with the inner walls of the flanges 29 are coated with material which will emit electrons at relatively low temperatures, this material preferably being an oxide or oxides of rare-earths, as for example strontium oxide or a mixture of strontium oxide and barium oxide. This coating may be formed by spraying the surfaces with a solution of the nitrate of the rare-earth, using an air-spray-gun for this purpose, and after drying reducing the nitrate to the oxide by heating the cap and the plate. I have found suitable for this purpose a solution consisting of two ounces each of barium nitrate and strontium nitrate and one-eighth ounce of pure gum arabic all dissolved in one quart of water heated to the boiling point. Heating a coating formed of this solution in a flame to a dull red heat for about fifteen seconds will reduce the nitrates to oxides. The

coating of the inner walls of the flanges 29 with the electron emitting material is not necessary for successful operation of the rectifier, this part being coated in the device constructed as described because when the spray is applied to the surface of the plate 21 the inner walls of the flanges unavoidably are sprayed unless special means are employed to prevent it, which however is unnecessary.

The walls, cap and plate thus constructed, in the assembled device illustrated form one electrode of the device, the other electrodes, of which I have herein shown two, being herein indicated at 33. For convenience the electrodes 33 are herein termed anodes and the electrode constituted by the plate and cap a cathode. The particular number of anodes employed as hereinafter explained depends upon the number of phases of the current to be rectified and upon whether only one or both sides of the wave are to be rectified. If for example only one side of the wave of a single phase current or one side of the wave of each phase of a two phase current is to be rectified the device need have but one anode.

As illustrated the block 17 is provided with the perforations 35 connecting the recesses 25 and 31 of the block. The anodes 33 as illustrated are in the form of relatively heavy wires which preferably are of nickel and extend through these perforations slightly into the interior of the cathode. With the connections shown by Fig. 8 it will be observed that the two anodes 33 in one sense constitute a condenser shunted across the ends of the input-transformer secondary, resulting in the potential between the anodes being greater than between the anodes and the cathode. There consequently is a tendency, especially at the peak of the wave, for arcing to occur across the anodes. The gas content of the bulb is a relatively poor dielectric, especially when hot; and herein, to prevent the possibility of arcing, a material of relatively high dielectric coefficient is placed between the anodes. I have found that Italian lava affords an excellent dielectric for insulating the parts from each other at the temperatures created during the operation of the device and at the same time is of itself heat resisting. Preferably the upper ends of the tubes 25 are spaced sufficiently from the cathode to remove said ends from the region of highest temperature. It will be observed that by this construction there is provided for each anode an insulating part of a high dielectric coefficient surrounding the anode and holding it in proper spaced relation to the cathode while insulating it from the cathode.

For holding the cathode and block 17 against longitudinal displacement relatively to the stem and for rigidly supporting the cathode I have herein illustrated a bifurcated member having tapered arms 37 formed integrally with a split ring 39 clamped about the exterior of the stem. Preferably the supporting member is formed of sheet steel and is initially made in two parts one of which is indicated in Fig. 7, each part comprising an arm 37 and one-half of the ring 39. Integral with each half of the ring are flanges 41 perforated at 43, and after each half of the supporting member is made the halves are placed together with the pair of flanges 41 in contact as is indicated in Fig. 6, and these flanges are then welded together at one end to form the completed supporting member which is clamped to the stem by means of the bolt 45 extending through a pair of aligned perforations 43. Herein for reinforcing the ring 39 the metal is folded back as indicated at 46 in Fig. 1, and for securing rigidity of the arms 37 the same are curvilinear in cross-section as indicated in Fig. 4. After the parts are assembled as hereinafter explained the upper ends of the arms 37 are welded to the edges of the plate 21 and the flange 23 of the cap 19, thereby securing the arms 37 to the cathode and placing the cathode in electrical communication with the cathode supporting member.

As illustrated in Fig. 1 lead wires 49 extend through the closed end 13 of the stem and connect with separate contact prongs 9. A third lead wire 51 extends through the closed end 13 of the stem and has connected thereto a conductor 53, preferably a length of nickel wire, which is welded to one of the arms 37 of the cathode supporting member as is indicated at 55 after the parts carried by the stem are assembled. The lead wire 51 is connected to one of the contact prongs 9, the fourth prong being left blank.

Conveniently the stem 11 with the tubes 15, anodes 33, and lead wires 49 and 51 are fabricated as a unit in a stem making machine such as is commonly used in connection with the manufacture of incandescent lamps. To this end a suitable block or fixture is employed for holding the parts in the relative positions shown by Fig. 3, after which the adjacent ends of the tube 11 and tube 15 are heated and squeezed together so as to fuse the tubes 15 to the tube 11 and fuse the lead wires 49 and 51 into the glass, the lead wires for this purpose conveniently being iron wire with a borated copper coating such as is commonly employed in incandescent lamp manufacture, or other suitable wire which will make a vacuum tight seal and has substantially the same coefficient of expansion as glass.

Referring to Fig. 2, in assembling the device illustrated the stem 11, with the tubes 15, anodes 33, and lead wires fabricated as a unit as explained above, is taken and the cathode supporting member is then placed thereon as indicated in Fig. 2. The block 17

is then placed in position on the tubes 15 with the anodes 33 projecting through the block, after which the plate 21 is positioned on the block and then the cap 19 positioned on the plate. The edges of the plate 21 and flange 23 and the upper ends of the arms 37 of the cathode supporting member are welded together at the points where the upper ends of these arms contact the edges of the plate and flange, the edges of the plate and flange between the arms preferably not being welded together or otherwise secured to each other so that the interior of the cap is in fluid communication with the exterior of the cap. The wire 55 may then be welded to one of the arms 57. The stem is then placed in the bulb and its flange 57 fused to the edge of the bulb. The bulb is now exhausted, after which preferably a small amount of inert conductive gas is admitted, this gas which is preferably a mono-atomic gas, such as helium, being in amount sufficient to create an absolute pressure in the order of 10 millimeters of mercury, the exact pressure depending upon the relation of the cathode and anodes as hereinafter explained and the amount of current to be carried by the rectifier.

In practice I have found that in order to secure best results the minimum space between the anode and cathode should not exceed a certain maximum, the value of which depends upon the kind of gas employed and its pressure. This maximum distance I believe is that which corresponds to the distance between the atoms of the gas at the existing pressure. As an example of satisfactory construction I have found that when using helium at a pressure of about 10 or 12 millimeters of mercury good results will be secured with a space of about .03 of an inch, as for example the anodes in the device illustrated may be about .065 of an inch in diameter and the perforation 27 in the plate 21 about .125 of an inch in diameter. With a rectifier constructed as indicated when the normal voltage is impressed upon the cathode and anodes ionization of the gas will be effected and the rectifier automatically will begin to function.

I have also found that by making the area of the cathode much greater than that of the anode the electrical efficiency and completeness of rectification are improved. In the device illustrated satisfactory results may be obtained by making the area of the cathode about 500 times that of that portion of the anode which projects above the bottom of the recess 31 in the lava block 17. I have found that such a construction reduces the back current to a few microamperes which is materially less than that of rectifiers as heretofore constructed, thus increasing the efficiency and completeness of rectification. In a device constructed as described the flanges 29 limit the effective areas of the anodes to their extreme tips, thus materially increasing the ratio of the area of the cathode surface to the area of the anode surfaces. This I explain is due to the fact that the distance between the anodes and the inner walls of the flanges 29 is less than the distance between the atoms of the gas, as heretofore described, thus preventing any ionization of the gas except that due to the charge between the cathode and the tips of the anodes.

With the present construction the anodes are each within the field of the other, which relation has been found to aid in increasing the effective output of the device. This action I explain as follows: Assume that the so-called anodes 33 are connected to the opposite ends of the secondary winding of the transformer and the so-called cathode 19 to the center tap of this winding as shown in Fig. 8. Then when one anode 33 is positive relative to the cathode 19 the other anode 33 is negative relative to the cathode. This causes a relatively large "forward current" to pass between the cathode 19 and that anode 33 which is positive relative to it, and a relatively minute current (the "back current") to flow between the cathode 19 and that anode 33 which is negative relative to it. The difference in the "forward" and "back" currents is of course the effective output current. By having each anode within the field of the other, the anode which at any one time is positive relative to the cathode, because it causes the larger forward current, tends to make the other anode less negative relative to the cathode by giving said other anode some of its positive charge, and this tends to reduce the back current which is already negligible by reason of the ratio of areas between the electrodes, and to steady and make more certain the operation of the device.

The shape of the cathode I have found may be varied, and although satisfactory results may be secured when it is constructed as illustrated other constructions may be employed, for example the cap portion 19 of the cathode may be omitted entirely, in which case the cathode may consist only of the plate 21. Preferably however the cathode is a substantially closed chamber effectively to shield the anodes and the ionic streams passing between the cathode and anodes and to eliminate the formation of a charge on the inner surface of the walls of the glass bulb. I have found that the shield renders the action of the device more steady and more certain.

In Fig. 8 I have indicated a schematic circuit diagram exemplifying one example of use of the specific rectifier hereinbefore described. Referring to Fig. 8 I have indicated at 59 the primary winding of a transformer on which may be impressed the alternating

electromotive force which it is desired to rectify. For example, this winding may be connected to opposite sides of the 60 cycle, single phase, 110 volt circuit commonly employed for house lighting. The secondary winding of the transformer is indicated at 61, one end of the winding being connected to one of the anodes 33 and the other end of the winding being connected to the other anode 33.

A lead 63 connected to the cathode which is represented at 65 forms the positive side of the rectified output, while the lead 67 which is connected to the neutral point of the secondary winding 61 forms the negative side of the output. If necessary I may employ any suitable means for filtering the rectified current, as for example by inserting a choke coil 69 in the lead 63 and by-passing the lead 63 to the lead 67 by suitable condensers 71. In the example given, wherein the primary voltage is 110 volts, I have found that satisfactory results can be obtained by designing the transformer to maintain a difference in potential of about 300 volts, in which case the difference in potential between the output leads 63 and 67 will be about 150 volts. I have found that satisfactory filtering may be effected when the choke coil 21 has an inductance in the order of 20 henries and the condensers 71 a capacity in the order of 4 microfarads.

In operation using the rectifier and circuit illustrated the current flows through the space in the hollow cathode when the cathode is negative relatively to the anode but substantially does not flow when the cathode is positive relatively to the anode. This phenomenon I explain is due to a nucleus of positive ions which is formed adjacent the anodes causing a positive space charge at this point acting to prevent ionization and consequent conduction when the cathode is positive, but permitting ionization and consequent conduction when the cathode is negative. Also I believe the phenomenon is in part due to the surface relation between the anode and cathode, which relation as explained above reduces the back current and permits substantially complete rectification at high electrical efficiency. When two anodes are employed, each connected to an opposite side of a phase of alternating electromotive force, and the cathode is connected to the neutral point of this phase, both sides of the wave in effect will be rectified because the negative impulse at a given side of the phase circuit has a displacement of 180° from the negative impulse at the other side of the phase circuit. In other words, if the output potential corresponding to the particular phase of impressed alternating electromotive force rectified were assumed to be of an undulatory character it would have a "frequency" of twice that of the impressed alternating electromotive force.

As further explaining the operation of the rectifier it will be understood that the normally neutral helium gas for a reason not clearly known at all times contains some free electrons all or some of which are ions. These ions apparently serve to initiate the operation of the rectifier when the alternating electromotive force is applied to the cathode and anodes, the occurring phenomena apparently being that these free ions in "falling" toward the anodes due to the impressed charge strike and break off ions from helium atoms, the residues of the atoms being positive causing them to "fall" toward the cathode and knock off ions from the electron emitting material of the cathode.

It will be observed that I am enabled to initiate the operation of the rectifier automatically without the employment of a spark or other auxiliary means for the purpose, and that the operation will continue without the necessity of a cathode heated to incandescence for causing electron emission, as heretofore has been proposed, and therefore I avoid cathode gas emission or other chemical actions due to high temperature tending to destroy the helium gas.

Heretofore it has been proposed to rectify the full wave by use of two rectifiers each having a pair of electrodes. I have found that with a rectifier constructed according to my invention, and having separate anodes for each side of the wave in the same container or bulb, I am able to obtain rectifier apparatus of the same electrical characteristics for each side of the wave, which is a practical impossibility when two separate rectifiers are employed for this purpose due, for example, to the unavoidably different gas content of each rectifier bulb. Further by my invention I am enabled to rectify the full wave more efficiently and with conservation of space, installment cost and replacement expense as compared with prior apparatus for this purpose.

Although in the above example I have explained the use of my device for rectifying a single phase current it will be understood that my invention is equally as applicable to rectifiers for polyphase currents, in which case if the full wave is to be rectified the number of anodes will not be less than two and there will be at least one anode for each phase, that is to say for example, for rectifying both sides of the wave there will be two anodes for single and two phase current and three anodes for three phase current. It will also be understood that although in the specific embodiment of my invention described the rectifier is particularly adapted for rectifying both sides of the wave of a single phase current, my invention is equally as applicable to rectifiers

in which but one side of the wave of a single or polyphase current is to be rectified. It will be further understood that although I have described one specific embodiment of my invention for illustrative purposes wide deviations may be made therefrom without departing from the spirit of my invention.

Claims:

1. A rectifier having in combination, a glass bulb, a tubular glass stem carried by an end of said bulb and opening to the exterior of said bulb at said end, said stem having a closed end carrying a glass tube integrally formed therewith, a body of insulating material carried by said tube, conductive material constituting a cathode carried by said body, a support for said cathode carried by said stem, conductive material constituting an anode in proximity with said cathode, a lead wire for said anode passing through said stem and the closed end thereof into said tube, and a lead wire for said cathode passing through said stem and the closed end thereof.

2. A non-thermionic rectifier having, in combination, a container of non-conductive material having therein a pair of conductors constituting anodes, conductive material formed to present a chamber the same portions of the interior walls of which are designed to coact with both anodes to provide a cathode, said chamber having perforations in the walls thereof into which said anodes extend, heat refractory insulating means of high dielectric coefficient insulating from each other the portions of said anodes adjacent the exterior of said cathode, said container and the interior of said chamber being filled with inert gas at low pressure, the spaces in the interior of said chamber about said perforations being in unrestricted gaseous communication, the interior walls of said chamber being coated with material for emitting electrons at relatively low temperatures, the effective portions of said anodes being within the fields of each other at potentials at which conduction occurs between said portions and the interior walls of said chamber.

3. A non-thermionic rectifier having, in combination, a container of non-conductive material having therein a pair of conductors constituting anodes, conductive material formed to present a chamber the same portions of the interior walls of which are designed to coact with both anodes to provide a cathode, said chamber having perforations in the walls thereof into which said anodes extend, said anodes being spaced from the walls of said perforations at such distances as will prevent conduction between them and said walls at potentials at which conduction occurs between them and the interior walls of said chamber, heat refractory insulating means of high dielectric coefficient insulating from each other the portions of said anodes adjacent the exterior of said cathode, said container and the interior of said chamber being filled with inert gas at low pressure, the interior walls of said chamber being coated with material for emitting electrons at relatively low temperatures, the effective portions of said anodes being within the fields of each other at potentials at which conduction occurs between said portions and the interior walls of said chamber.

4. A non-thermionic rectifier having, in combination, a container of non-conductive material having therein in spaced relation to its walls conductive material formed to provide a chamber the walls of which have perforations, said container and chamber being filled with conductive inert gas at low pressure, the spaces in the interior of said chamber about said perforations being in unrestricted gaseous communication, a pair of conductors in said container extending into said perforations in spaced relation to the walls thereof, heat refractory insulating means of high dielectric coefficient insulating from each other the portions of said conductors adjacent the exterior of said chamber, and leads for connecting said conductors and the walls of said chamber with the exterior of said container.

5. A non-thermionic rectifier having, in combination, a container of non-conductive material having therein in spaced relation to its walls conductive material formed to provide a chamber the walls of which have perforations, the interior walls of said chamber being coated with material for emitting electrons at relatively low temperatures, said container and chamber being filled with conductive inert gas at low pressure, the spaces in the interior of said chamber about said perforations being in unrestricted gaseous communication, a pair of conductors in said container extending into said perforations in spaced relation to the walls thereof, heat refractory insulating means of high dielectric coefficient insulating from each other the portions of said conductors adjacent the exterior of said chamber, and leads for connecting said conductors and the walls of said chamber with the exterior of said container.

6. A non-thermionic rectifier having, in combination, a container of non-conductive material having therein in spaced relation to its walls conductive material formed to provide a chamber the walls of which have perforations, said container and chamber being filled with conductive inert gas at low pressure, the spaces in the interior of said chamber about said perforations being in unrestricted gaseous communication, a pair of conductors in said container extending into said perforations in spaced relation to the walls thereof at such distances as will prevent conduction between said conductors and said walls at potential differences at which conduction occurs between said conductors and the interior walls of said chamber, heat

refractory insulating means of high dielectric coefficient insulating from each other the portions of said conductors adjacent the exterior of said chamber, and leads for connecting said conductors and the walls of said chamber with the exterior of said container.

7. A non-thermionic rectifier having, in combination, a container of non-conductive material having therein in spaced relation to its walls conductive material formed to provide a chamber the walls of which have perforations, said container and chamber being filled with conductive inert gas at low pressure, the spaces in the interior of said chamber about said perforations being in unrestricted gaseous communication, a pair of conductors in said container extending into said perforations and presenting portions of relatively small area opposed to the interior walls of said chamber, heat refractory insulating means of high dielectric coefficient insulating from each other the portions of said conductors adjacent the exterior of said chamber, and leads for connecting said conductors and the walls of said chamber with the exterior of said container.

8. A non-thermionic rectifier having, in combination, a glass bulb, a hollow glass stem formed integrally with said bulb and situated interiorly thereof, the inner end of said stem being closed, glass tubes formed integrally with and projecting from the closed inner end of said stem, a hollow cathode spaced from the ends of said tubes and having openings substantially aligned with said tubes, conductors extending through the closed inner end of said stem and said tubes into said openings to form anodes, means insulating from each other those portions of said conductors which are between the ends of said tubes and said openings comprising material of high dielectric coefficient more heat refractory than glass surrounding the portions of said conductors adjacent said openings.

9. A non-thermionic rectifier having, in combination, a glass bulb having therein a cathode, conductors extending into said bulb into proximity with said cathode to form anodes, means spacing said cathode from the walls of said bulb comprising glass tubes and material of high dielectric coefficient more heat refractory than glass extending from the ends of said tubes to said cathode, said tubes being carried in fixed relation to the walls of said bulb, said conductors passing through said material and tubes, the latter being sealed to provide a gas tight joint with said conductors.

10. A non-thermionic rectifier having, in combination, a glass bulb having formed integrally therewith an inwardly projecting hollow glass stem with a closed inner end carrying tubular glass projections, a hollow cathode spaced from the inner end of said projections, conductors extending through the closed inner end of said stem and through said projections, the end portions of said conductors to coact with the interior walls of said cathode to provide anodes, insulating means of high dielectric coefficient more heat refractory than glass insulating from each other those portions of said conductors which are between said cathode and the ends of said projections; opposite end portions of said material cooperating with coacting portions of said cathode and projections to hold the parts in alignment.

11. A rectifier having, in combination, a glass bulb, a hollow glass stem formed integrally with said bulb and situated interiorly thereof, the inner end of said stem being closed, glass tubes formed integrally with and projecting from the closed inner end of said stem, a cathode spaced from the inner ends of said tubes, conductors extending through the closed inner end of said stem and through said tubes into proximity with said cathode to form anodes, heat refractory material of higher dielectric coefficient than glass insulating from each other those portions of said conductors which are between the ends of said tubes and cathode, supporting means for said cathode carried by said stem, said supporting means being of conducting material and in electrical communication with said cathode, and a lead connected to said supporting means and extending through the closed end of said stem.

12. A rectifier having, in combination, a glass bulb, a hollow glass stem formed integrally with said bulb and situated interiorly thereof, the inner end of said stem being closed, glass tubes formed integrally with and projecting from the closed inner end of said stem, a cathode spaced from the inner ends of said tubes, conductors extending through the closed inner end of said stem and through said tubes into perforations in said cathode, material of high dielectric coefficient more heat refractory than glass insulating from each other those portions of said conductors which are between the inner ends of said tubes and said cathode, said heat refractory material having recesses receiving the ends of said tubes, said cathode and said heat refractory material adjacent the perforations in said cathode being provided with means whereby one of said members projects into the other.

13. A non-thermonic rectifier having, in combination, a glass bulb, a hollow glass stem formed integrally with said bulb and situated interiorly thereof, the inner end of said stem being closed, glass tubes projecting from the closed inner end of said stem, a hollow cathode spaced from the ends of said tubes, said cathode having openings in the walls thereof, conductors of relatively smaller cross-section than the size of said

perforations extending through said tubes and perforations into said cathode, means spacing said conductors from the walls of said perforations and insulating from each other those portions of said conductors which are between said cathode and the ends of said tubes, said means comprising a body of material of high dielectric coefficient, more refractory than glass, said material coacting with said cathode and being provided with apertures, said conductors being received in said apertures.

14. A rectifier of the gaseous type comprising a hollow cathode substantially closed except for restricted openings of small dimensions compared to the corresponding dimensions of the cathode, and anodes presented to the interior of the cathode through said openings respectively said anodes being smaller than said openings, forming a space between the latter and said anodes of dimension insufficient to support substantial conduction.

15. A rectifier comprising a tube having a reentrant stem, a cathode having a substantially plane metallic wall provided with openings therein, anodes presented to the cathode through said openings, said cathode and anodes being mounted on said stem and the space between the anodes being unobstructed.

16. A glow discharge rectifier comprising a tube containing inert gas, a hollow cathode and separate anodes on the same side of the cathode, the parts being arranged for gaseous discharge between the anodes and the interior of the cathode, and insulation means for restricting discharge between the anodes and the exterior of the cathode, the regions about said anodes intercommunicating inside the cathode.

17. A rectifier comprising a cathode having a substantially closed boundary and terminating at one end in a metallic wall, anodes arranged for electronic discharge between areas of the anodes and the interior of the cathode, and common means for restricting discharge from one anode to the other and from the exterior of the cathode to the active surface of either anode the regions about said anodes intercommunicating inside said cathode.

18. A rectifier comprising a cathode having openings therein and anodes having portions presented to the cathode through said openings, the areas of said anodes being confined substantially to the areas of said openings and separated from each other sufficiently to prevent arcing therebetween, the spacing between each anode and its opening being sufficiently short to prevent substantial ionization by electrons taking their shortest paths between the peripheries of the openings and the anodes.

19. A rectifier comprising an obstruction having spaced openings therethrough, anodes presented to said openings respectively, from one side of the obstruction, a cathode surface on the other side of said obstruction, and insulation means surrounding the anodes in close juxtaposition to said first side of the obstruction said openings being in line with said anodes respectively and spaced therefrom an insulatingly short distance and the flow of current being obstructed except through said openings.

20. A glow discharge device comprising an envelope containing gas an obstruction having spaced openings therethrough, anodes presented to said openings respectively from one side of the obstruction, a cathode on the other side of said obstruction, said openings being confined to locations in line with the anodes respectively and spaced therefrom an insulatingly short distance.

21. A rectifier comprising a cathode having electron discharge openings, anodes presented to said openings, and insulation means surrounding the anodes and contacting with the cathode around each opening the regions adacent the ends of the anodes freely intercommunicating with each other.

22. A glow discharge rectifier comprising a tube containing inert gas and having at one end a base for attachment to a socket, a hollow cathode having openings directed toward said end, anodes presented to the interior of said cathode through said openings respectively from said end, and leads extending from the cathode and anodes to said base, the regions adjacent the ends of the anodes intercommunicating inside the hollow cathode.

23. A rectifier comprising a tube having at one end a base for attachment to a socket, a cathode having openings directed toward said end, anodes presented to the cathode through said openings, means for causing the current between the cathode and anodes to pass through said openings, and leads extending from the cathode and anodes to said base, said means including a space between each anode and the periphery of its opening so short that electrons traveling across the space produce insufficient ionization to initiate substantial conduction.

24. A rectifier comprising a tube having at one end a base for attachment to a socket, a cathode having openings directed toward said end, anodes presented to said cathode through said openings, means for causing the current between the cathode and anodes to pass through said openings, a reentrant stem carrying said cathode and anodes, said stem having separate projections for said anodes, and leads extending from the cathode and anodes to said base, said means including a space between each anode and the periphery of its opening so short that electrons travel-

ling across the space produce insufficient ionization to initiate substantial conduction.

25. An electric discharge device comprising an envelope having a reentrant stem, a cathode beyond the end of the stem, tubes projecting from the end of said stem side by side, anodes projecting from said tubes in operative relation to said cathode, and insulation material surrounding said anodes beyond the ends of the tubes, said tubes being integral with said stem so that the anodes are held in fixed predetermined relationship to each other by means fast to the envelope.

26. An electric discharge device comprising an envelope having a reentrant stem with two parallel tubular projections integral therewith, anodes projecting from said projections, insulating material around said anodes beyond said projections, and a cathode having spaced openings in the region of the ends of said anodes respectively, said openings being spaced the same as said projections so that the anodes are centered on the openings respectively.

27. An electric discharge device comprising an envelope having two internal projections integral therewith, anodes mounted on said projections, insulation material surrounding each anode, having a portion interfitting with and fitting over its said projection, a cathode having an opening for each anode, and interfitting with said insulation material at each opening, whereby the cathode and anodes are held in fixed relationship radially of said openings.

28. A rectifier comprising an obstruction having spaced openings therethrough anodes presented to said openings respectively from one side of the obstruction, the surface of the obstruction remote from said anodes adapted to function as a cathode, said obstruction substantially restricting flow of space current except through said openings.

29. An electric discharge device comprising an envelope, internal tubular projections integral therewith, co-operating cathode and anodes, the cathode surrounding all of said anodes and insulating material surrounding each anode beyond the end of the corresponding projection and telescoping with the projection, the anodes being mounted in said projections respectively whereby the anodes are held in fixed predetermined relationship to each other by means integral with the envelope.

30. A gaseous conduction device comprising an envelope containing a gas, more than two electrodes, each electrode being insulated from the other, said electrodes adapted to conduct electricity between them only through said gas insulating means mechanically interconnecting said electrodes, only the paths of the longer lines of electrostatic stress going through said insulating means, and an insulating gap between two of said electrodes, the paths of the shortest lines of stress between said two electrodes going through said insulating gap, a portion of one of said two electrodes being mounted between the other of said two electrodes and the remaining electrode, the paths of the shortest lines of stress between said last two named electrodes going through the electrode mounted therebetween.

31. A rectifier comprising two electrodes in gaseous conduction relation with a third electrode, insulating means supporting said electrodes, said insulating means being cut away around two of said electrodes to provide a gap between each of said electrodes and the third electrode, the gap being of such width that there is a substantial absence of ionization in said gap.

32. A rectifier comprising a hollow cathode, a plurality of openings in said cathode, anodes in said openings, insulation supporting said cathode and anode with respect to each other, said insulation being cut away to form insulating gaps at the active surfaces of said anodes.

33. A rectifier comprising a gas-filled envelope, a stem therein, means supporting a cathode and a plurality of electrodes thereon, said cathode being hollow and having a plurality of openings, insulation having openings, electrodes presented through said openings to said cathode, said insulation being spaced from the boundaries of said electrodes to provide annular insulating gaps.

In testimony whereof, I have signed my name to this specification.

THORNDIKE F. CHENEY.