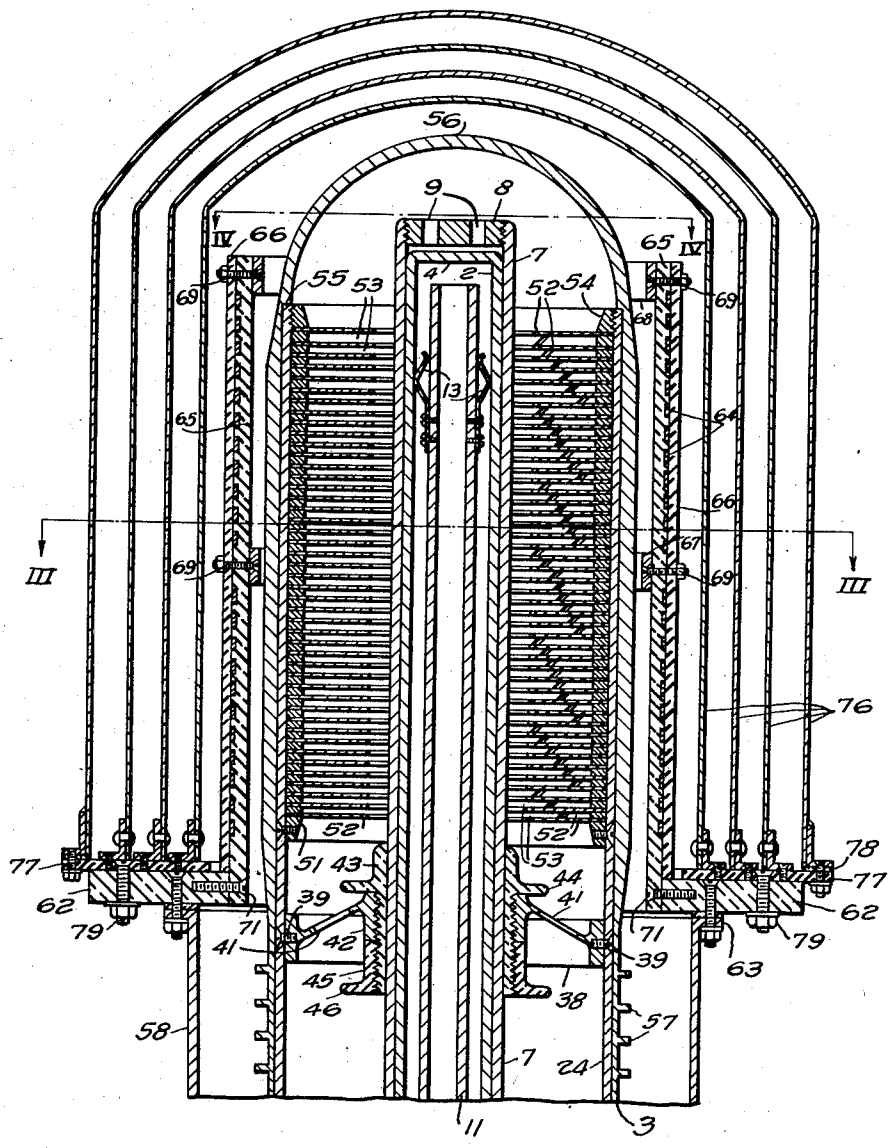
May 11, 1937. E. F. LOWRY 2,080,284

THERMIONIC RECTIFIER

Filed July 30, 1932 4 Sheets-Sheet 1

Fig 1.



WITNESSES

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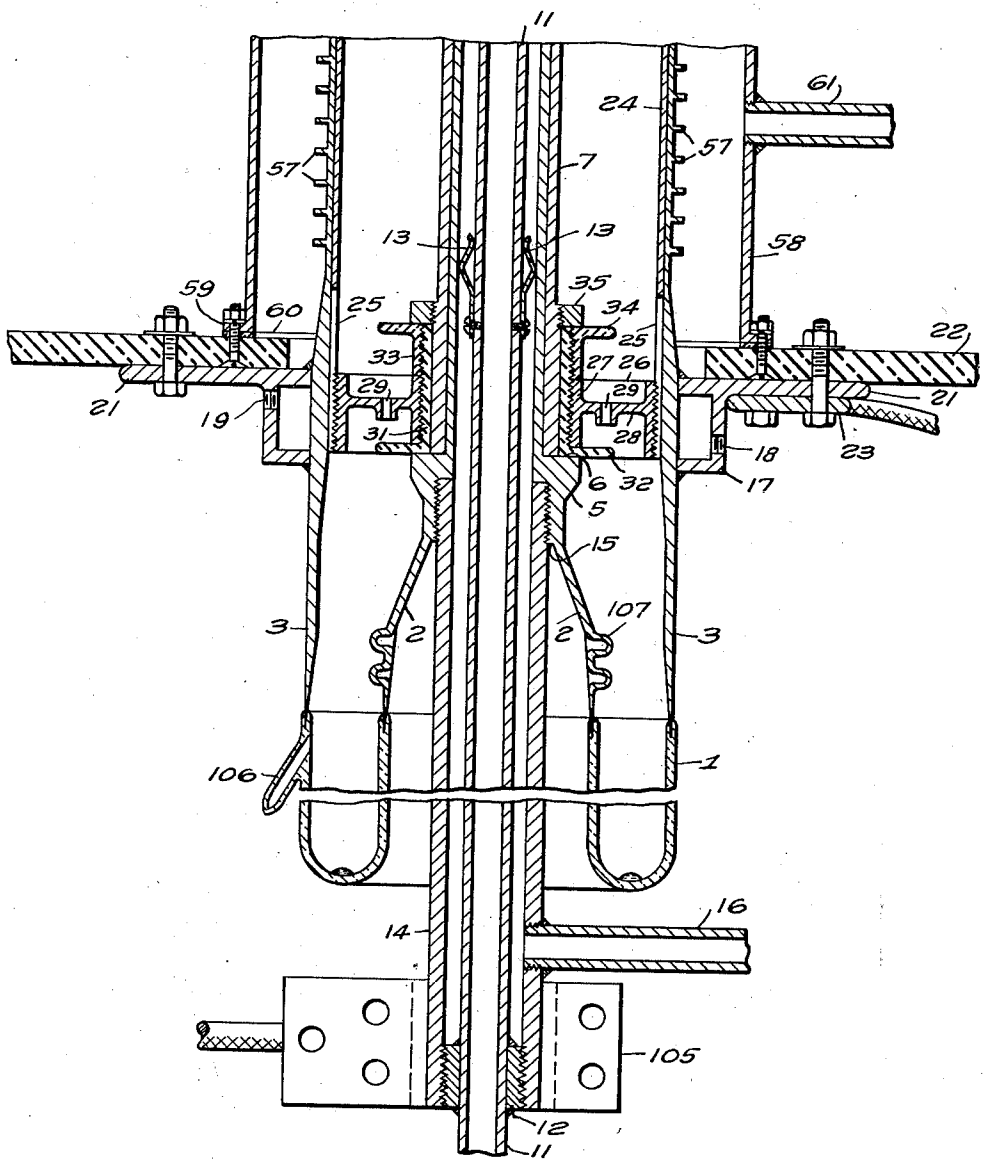
ATTORNEY

May 11, 1937. E. F. LOWRY 2,080,284

THERMIONIC RECTIFIER

Filed July 30, 1932 4 Sheets-Sheet 2

Fig. 2.



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THERMIONIC RECTIFIER

Filed July 30, 1932 4 Sheets-Sheet 3

Fig. 3.

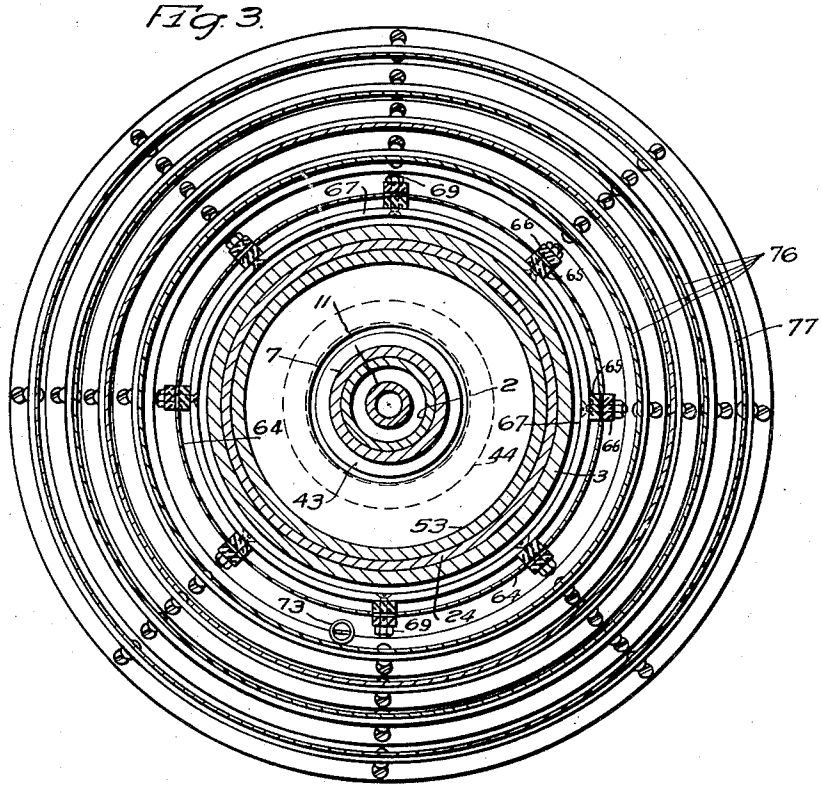
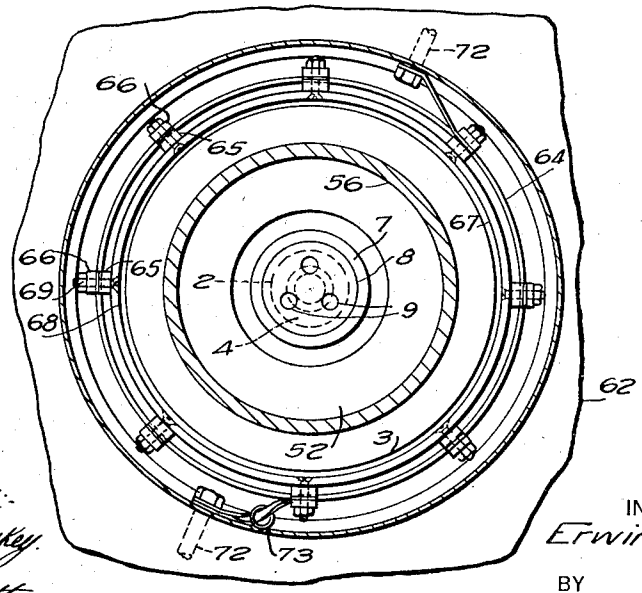


Fig. 4.



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THERMIONIC RECTIFIER

Filed July 30, 1932 4 Sheets-Sheet 4

Fig. 5.

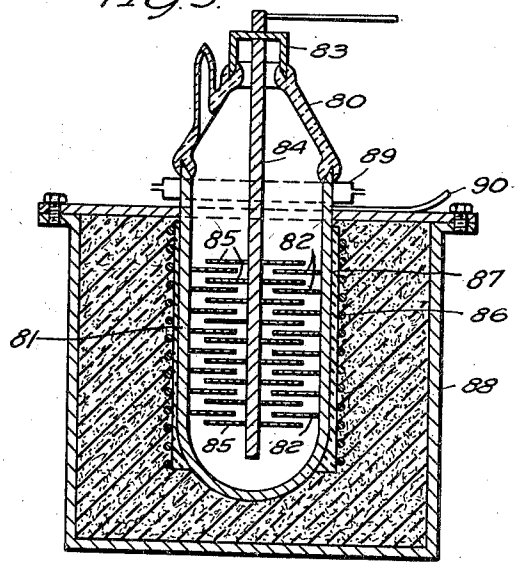


Fig. 6.

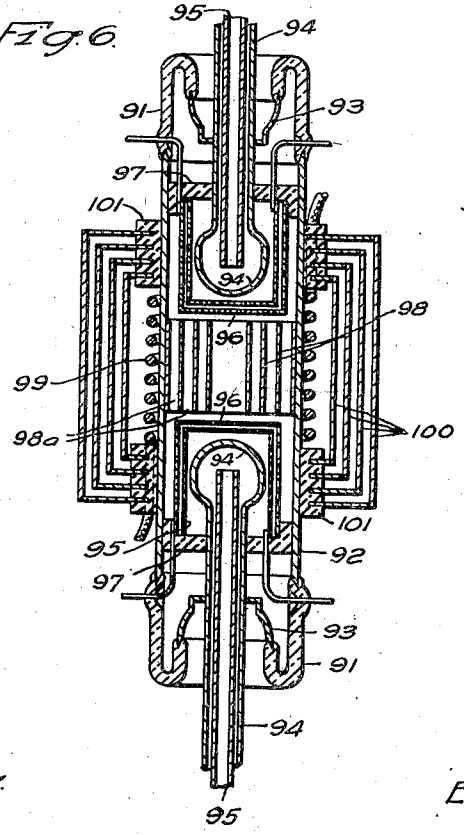
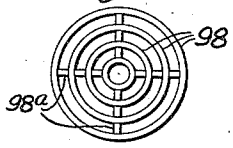


Fig. 7



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Patented May 11, 1937 2,080,284

UNITED STATES PATENT OFFICE

2,080,284

THERMIONIC RECTIFIER

Erwin F. Lowry, Forest Hills, Wilkinsburg, Pa., assignor to Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., a corporation of Pennsylvania

Application July 30, 1932, Serial No. 626,853

11 Claims. (Cl. 250—27.5)

This invention relates to hot cathode tubes and particularly to tubes of this type intended for heavy currents, such as power rectifiers.

When the current to be carried by a tube is large, the cathode must have a great area because, the electron emission per unit area of the cathode is limited, as indicated by the well known Richardson equation.

In gaseous discharge devices, directly heated cathodes and the heaters for indirectly heated cathodes, when they are exposed to the discharge space, may not have impressed upon them more than about 5 or 6 volts because a discharge between their ends must be avoided. If the area of the cathode be large, the radiation will be large, and the energy supplied must, therefore, be large to obtain the necessary temperature. For this reason, the current supplied at the low potential just indicated must exceed that which can conveniently be supplied through the necessary leads and seals. In the direct-heated type of cathode, when the emission currents become of the same order of magnitude as the heated current, they cause serious non-uniformity in the cathode temperature, which materially shortens the life of the cathode.

It is an object of my invention to provide a tube capable of carrying currents much heavier than have heretofore been possible.

It is a further object of my invention to provide a tube with a cathode of large area substantially uniformly heated.

It is a further object of my invention to provide an arrangement for heating the cathode in which the losses by radiation are not such as to introduce irregularities in temperature.

It is a further object of my invention to provide means for heating the cathode energized directly from a source of ordinary commercial potential, such as 110 volts, whereas a heater within the envelope of the tube is restricted to about 5 volts as explained above.

It is a further object of my invention to provide a grid which shall have the same heat-shielding effect as an imperforate sheet of metal.

I accomplish these objects by making one portion of the wall of the tube also a portion of the cathode, and applying heat thereto from a heat source exterior to the tube. By surrounding the heat source with a device which hinders radiation in a direction outward from the tube, I produce a condition in the region occupied by the cathode similar to that in the interior of a "black body" and there is substantially no departure of heat from this region except by conduction through the anode.

For details of the structures employed and for still further objects of my invention, reference is made to the following description and the accompanying drawings in which:

Figures 1 and 2 are central vertical sections of the preferred form of tube. Fig. 1 being the upper portion and Fig. 2 the lower portion thereof.

Fig. 3 is a transverse section on the line III—III of Fig. 1,

Fig. 4 is a similar section on the line IV—IV of Fig. 1,

Fig. 5 is a central longitudinal section of a modified form of tube,

Fig. 6 is another modification in which a tube having two anodes is shown, and Fig. 7 is a top view of the cathode of Fig. 6.

The envelope of the tube shown in Figs. 1 and 2 comprises a glass portion 1 in the form of an annular trough, an inner copper wall 2 sealed to the inner edge of the trough 1 and an outer copper wall 3 sealed to its outer edge.

The inner wall 2 has the form of an elongated thimble having a top or closure 4 integral therewith. It also has an enlargement 5 providing a seat 6 against which a nickel sleeve 7 abuts. The nickel sleeve extends from the seat beyond the top 4 and is closed by a nickel plug 8 through which perforations 9 extend.

A copper pipe 11 is centered within the thimble, being secured at the outer end by a threaded plug 12 and held in its central position relative thereto by springs 13 at a plurality of places along the pipe 11. The plug 12 is threaded into a copper pipe 14, the other end of which is threaded at 15 into the inner part of the enlargement 5. A branch pipe 16 affords exit from the annular space between the pipe 11 and the interior of the thimble and the pipe 14. Provision is thus made for circulation of water or other cooling fluid through the interior of the thimble.

A water jacket 17 is secured to the exterior of the copper wall 3 in any suitable manner. As shown on the drawings (Fig. 2), this is done by silver solder or similar fusible joining material. When it is desired to avoid danger of deforming the copper wall 3 the jacket 17 may be secured thereto by threads or by any fastening that affords sufficient mechanical strength without perforating the wall.

An inlet 18 and an outlet 19 are shown to indicate that water or other cooling fluid is to circulate in the jacket 17. A flange 21 on the

jacket 17 affords means by which the tube may be secured by the supporting plate 22 of insulation. A connector 23 is shown at the right of Fig. 2 by which a lead is connected to the wall 3.

The outer copper wall 3 has a thickened portion at the place where the water jacket 17 is secured, in order to afford sufficient mechanical strength to support the weight of the tube. Any difference in thermal expansion between the walls 2 and 3 is provided for by corrugating one of them between the main body and the seal such as the corrugations 107. From the thickened portion upward the wall 3 is lined with a nickel sleeve 24, the lower portion of which is provided with slits as shown at 25 by means of which the sleeve is capable of being radially deformed slightly in order to secure close contact between it and the copper wall 3.

An exteriorly threaded ring 26 cooperates with threads in the slitted portion of the nickel sleeve 24. The threaded portions of the ring and the sleeve taper very slightly, whereby adjustment of the ring 26 will force the nickel sleeve into close contact with the copper wall. The ring 26 has a hub 27 connected to the circumferential part by a web 28 having perforations 29 each surrounded by a skirt extending downwardly.

The ring 26 is insulated from the nickel sleeve 7 by a collar 31 of lavite or similar insulating material. The collar is provided with a flange 32 which abuts against the seat 6 and by projecting beyond the edge of the seat and beyond the hub 27 the ring affords a path long enough to prevent leakage. The lavite collar 31 is threaded on its exterior to cooperate with threads on the interior of the hub 27 and also with threads on the interior of a second lavite sleeve 33 which is also provided with a flange 34. The two lavite sleeves are restrained from motion away from the seat 6 by a steel collar 35 which is threaded onto the nickel sleeve 7.

The weight of the nickel sleeve 7 is transferred to the thickened part of the wall 3 and thus to the shelf 22 through the jacket 17 by this connection of the nickel sleeve and the ring 26.

The sleeve 7 and plug 8 constitute the anode. The ring 26, mechanically connected to but insulated from the anode, is part of the anode structure although not electrically part of the anode; that is, its weight as well as the weight of the anode proper and of the copper wall 2 is carried by threading the ring 26 into the nickel sleeve 24. The seal at the bottom of the thimble 2 is thus released of mechanical strain.

The nickel sleeve 7 is centered relative to the exterior wall 3 by the ring 26 and by a spider 38 which is secured to the nickel sleeve 24 in any suitable manner, such as by screws 39. The spokes 41 of the spider are oblique to the plane of its outer ring and can yield to provide changes in the distance between the sleeve 24 and the hub 42 of the spider 38 caused by thermal expansion and contraction.

A lavite insulator 43 with a flange 44 has a slip-fit on the nickel sleeve 7. Between the flange 44 and the lower end of the insulator, it is threaded on its outer surface to cooperate with the threaded interior of the hub 42. A second insulating member 45 with a flange 46 is threaded onto the insulator 43 below the hub 42.

A nickel ring 51 is secured to the nickel sleeve 24 at the level of the insulator 43 or slightly above it. A series of annular nickel discs 52 separated by spacing rings 53 also of nickel is stacked within the sleeve 24 and rests upon this ring 51.

The discs 52 may be of "Konel" or other suitable metal instead of nickel. The portions of their surfaces free from the rings 53 are coated with emissive material as explained below. Each ring 53 is preferably split at one point and, in its unrestrained position, is of somewhat larger diameter than the sleeve 24. The rings 53 thus exert sufficient pressure against the sleeve 24 to ensure good electrical contact therewith. Good electrical contact between discs 52 and rings 53 is obtained by screwing ring 54 tightly against the stack of rings and discs. The ring 51 is secured in place in any suitable manner. It may be integral with the sleeve 24 or it may be secured thereto by screws as shown.

At the top of the stack, a ring 54, similar to the ring 51, is preferably threaded into the sleeve 24. The top of this ring and the top of the sleeve are flush and the whole cathode structure is definitely positioned selective to the copper envelope 3 by the top of sleeve 24 fitting against a seat 55 provided in the copper wall 3. The tight contact between the metallic portions of the discs 52, sleeve 24 and copper wall 3 makes a substantially electrical integral combination.

The portion of the walls adjacent the stack is preferably thickened as it is adjacent the water jacket 17, and the dome 56 in which the wall terminates is also thick, being of substantially the same thickness as the thickened portion near the stack of discs.

Between the two, thickened portions, the wall 3 is thinner and is provided on its outer surface with ribs 57. The space into which these ribs project is enclosed by a steel sleeve 58 which rests upon and is secured to the shelf 22. A flange 59 on the sleeve 58 facilitates the fastening and a gasket 60 prevents gas-leakage between the flange and the shelf 22. The sleeve 58 and the parts carried thereby are mechanically and electrically free of the tube and the parts carried by it.

A branch pipe 61 extends from the sleeve 58 and is preferably connected to any suitable reservoir containing material for absorbing oxidizing gases, leaving the interior of the tube 58 and its associated parts preferably filled with substantially pure nitrogen.

The top of the tube 58 is preferably secured to a plate 62 of lavite or any similar insulating material, the flange 63 being provided for that purpose and a gasket being inserted at the joint also.

A coil 64 of heater wire such as nichrome is preferably supported above the plate 62. The support comprises vertical strips 65 of lavite or similar insulating material and thinner strips 66 likewise of lavite. Rings 67 and 68 and bolts 69 clamp the strips 65 and 66 against the coil 64. At the bottom of the inner and longer strips 65 they are secured to the plate 62 by screws 71.

The coil 64 is enclosed by a plurality of nested spaced shields 76 of bright nickel. Each shield comprises a cylindrical portion and a dome and is secured by means of a ring and bolts to a ring 77, preferably of insulation. The several shields are thus mechanically secured together and can be removed or replaced as a unit. Bolts 79 secure this unit to the plate 62. The outermost shield is separated from the insulating ring 77 by a gasket 78 which prevents the interchange of gas between the atmosphere and the nitrogen filling the space within the sleeve 58.

At two points, bolts 72 extend completely through one or more of the shields 76 and up to

the plate 62. The ends of the heater wire 64 are attached to the inner ends of the bolts 72 and the outer ends of these bolts serve as connectors for the supply of heating current. The upper end of the coil 64 is led to the level of the plate 62 through a tube 73 of porcelain or other insulating material. This structure can be seen in Figures 3 and 4. The plane in which Fig. 1 is taken does not include 72 and 73.

A small amount of mercury is preferably placed inside of the tube. In the illustrated position, the mercury will collect in the bottom of the glass trough 1. If the tube be placed the other end up, the mercury will flow into the space between the hub and the outer wall of the ring 26. The skirts around the openings 29 will be sufficient to prevent the liquid mercury from passing the web of the ring 26, but mercury vapor can readily pass through the openings 29.

When my invention is applied to a tube intended for use at higher potentials, for example, in supplying X-ray tubes, it may be desirable to omit mercury vapor or other gas and pump the tube to as high a vacuum as is possible. A tube for this purpose is illustrated in Fig. 5. It has a glass portion 80 to which a copper envelope 81 is sealed. Annular fins 82, preferably of nickel coated with an emissive substance, extend inwardly from the envelope 81. The upper portion of the glass part 80 is sealed to a copper entrance piece 83 through which an anode 84 extends.

The anode is supplied with the usual lead and preferably with discs 85 which interleave with the discs 82. The discs 85 are of metal, uncoated or coated with carbon. A heating coil 86 around the outside of the cylindrical part of the envelope 81, is separated therefrom by insulation 87. The tube and heating coil are enclosed in a case 88 which is filled with thermal insulation.

Between the heated portion of the copper envelope 81 and the seal uniting it to the glass portion 80, a cooling device such as a water jacket 89 is provided. A cathode lead 90 is connected to the envelope 81 above the case 88.

A form of my tube which is adapted for complete-wave rectification with a single tube is shown in Fig. 6. Two glass portions 91 are provided with seals for union with a central copper portion 92 and with seals for union with a pair of separated metallic portions 93. The anodes 94 are connected to the exterior through the metallic caps 93 and pipes 95 conduct water or other cooling fluid to the interior of each anode.

Each anode may be surrounded by a grid 96 to permit the tube to function as a grid glow tube. Similar grids may be used in the other forms of tubes if it is desired to use them for grid glow tubes. The grids are each mounted upon a shelf of insulation 97 or on any suitable support. The grids are each preferably made of two sheets of perforated metal, the perforations in one sheet being opposite the imperforate parts of the companion sheet. Suitable conductors through the necessary seals connect each grid to the exterior.

It is permissible to unite the two sheets into a single grid but for many uses it is preferable to provide each sheet with a separate lead to the exterior, whereby the potentials impressed on the sheets may be made to differ when desired. The size of the perforations and the distance between the sheets of each grid are determined by the desired characteristics of the tube. If the holes are too small and the sheets too near together, the tube fails to conduct at any part of the cycle. If the holes are too big and the sheets too far apart, the potentials impressed upon the grid will not control the tube. Approach to the first extreme is indicated by the tube not performing as intended until an additional positive potential is impressed upon the grid and an approach to the other extreme causes a more negative grid-potential to be required to obtain the intended control.

The cathode comprises the central copper portion 92 and a plurality of nickel cylinders 98 united both terminally and electrically by nickel spacing webs 98a. The outermost cylinder 98 is connected to the copper wall 92 mechanically and electrically. The wall 92 is thus part of the cathode and a lead (not shown) is connected to it at any convenient point.

A heater 99 surrounds the outside of the copper wall 92 and is surrounded by a plurality of nickel shields 100 mounted in any suitable insulating supports 101 through which the terminals of the heating coil 99 are brought out.

In the manufacture of the form of my device illustrated in Figs. 1 to 4, the nickel sleeve 7 and plug 8 are subjected in a furnace to the action of a suitable hydrocarbon, such as natural gas or butane. This deposits a layer of carbon upon the plug and the outer surface of the nickel sleeve 7 and in the heat of the furnace an integral composite layer of carbon and nickel is formed on the sleeve and plug. During the treatment the inner surface of the sleeve is protected by plugging the ends. The parts are then allowed to cool and the excess carbon is wiped off.

If desired a graphite sleeve may be substituted for the portion of the nickel sleeve involved in the discharge phenomena.

Then these parts, as well as all of the parts which are finally enclosed within the envelope are vacuum treated. This includes the parts made of lavite, as well as the parts made of metal. The treatment consists in subjecting them to heat in a vacuum by means of which absorbed gases are removed.

The portions of the discs 52 and rings 53, which, in the finished tube, are exposed, are next coated with a mixture of the carbonates of barium and strontium. One convenient way of doing this is to assemble the rings 53 in a holder so that their inner surfaces make one continuous cylindrical surface and spray this surface with a solution of carbonates. Each of the discs 52 is placed in a holder which covers the portion that is finally to be between two rings 53 and the uncovered portions of the discs are sprayed with a similar solution.

The portions which constitute the anode structure are assembled, the nickel sleeve 7 being shrunk onto the copper thimble 2 and the ring 26 with its associated parts being screwed into place. At this time the glass portion is in two parts. The inner part of the glass is sealed to the bottom of the thimble 2.

The parts which are to be carried by the nickel sleeve 24 are next assembled thereon. First, the ring 51 is attached to the nickel sleeve 24. Then the stack of discs 52 and rings 53 is built within the sleeve resting upon the ring 51. The lowest two discs and the upper two are preferably uncoated. Each ring 53 must be compressed in order to get it into the sleeve 24. When all of the rings 53 and discs 52 are in place, the ring 54 is forced against them by screwing it into the open end of the nickel sleeve 24.

As it is screwed into place, it compresses the stack, bringing all the rings 53 and discs 52 into close electrical contact with each other.

The spider 38 and the parts associated therewith are next put in place and secured by the screws 39 to the nickel sleeve 24. The copper envelope 3 is then slipped into place on the outside of the nickel tube 24. The seat 55 contacting with the upper end of the sleeve 24 ensures the correct position of these parts. The thickened portion of the wall 3 surrounding the stack fits the nickel sleeve 24 tightly, thereby ensuring good electrical contact. The thickness of this part of the wall 3 gives it the mechanical strength to sustain the pressure of the tight fit which may be a press fit but preferably is obtained by shrinking the wall 3 onto the nickel lining 24.

When the parts supported by the wall 3 and the parts supported by the thimble 2 have been assembled upon their respective parts of the envelope, the outer part is placed around the inner part by slipping the insulator 43 over the end of the tube 7 and moving it and the parts assembled with it along the sleeve until the threads on the split portion of the sleeve 24 engage the threads upon the ring 26. Then one part of the envelope is rotated relative to the other until the lower edge of the wall 3 is opposite the lower edge of the wall 2.

The outer part of the glass trough 1 is then sealed to the wall 3. After this, the two portions of the annular glass trough 1 are united by fusing them together. Then the pumping process is carried out through the usual tubulation 106.

The pumping process is carried out in the usual way and includes heating the tube to remove absorbed gases. Incidentally, this treatment converts the carbonates into oxides, covering all but the two end pairs of discs. Near the end of the pumping treatment a little mercury is distilled into the tube. After the pumping is over and the tube has been sealed, it is allowed to cool and the mercury then collects in the bottom of the glass trough.

Because the hydrocarbon was removed by the vacuum treatment of the several parts, the copper will not deteriorate during the heat treatment incident to pumping, for if the removal of the hydrocarbons were neglected or were incompletely carried out, there is serious danger that a leak will develop through the copper where it is made thin to provide for the seals.

When the tube has been thus treated, the sleeve 58 and the furnace consisting of the heater 64 and its associated shields are put in place. The space between the shields 76, the sleeve 58 and the tube proper may be filled with nitrogen at the time the shields are put in place or the action of the chemicals connected to this space through the pipe 61 may be relied upon to gradually change the air into nitrogen. Only the outer shield 76 is provided with a gasket. There is consequently sufficient leakage past the other shields to effect the gradual removal of oxidizing gases from the space between them even if this space were not filled with nitrogen at the time of assembling the device.

In the operation of the device current from any convenient source, such for example, as a 110 volt circuit, is supplied to the bolts 72 and consequently, heat is generated in the heating coil 64 and reaches the copper wall 3 by radiation. Radiation in the opposite direction is prevented, or at least minimized, by the shields 76.

The insulation 62 and 77 prevents conduction of heat from one shield 76 to the other. Effective reflection is thus obtained at both faces of every shield.

Because radiation outwardly from the heater 64 is prevented, the heat delivered to the wall 3 can travel only inwardly. The nickel sleeve 24, the rings 53 and the discs 52 are heated by conduction from the wall 3. From the inner edges of the discs 52, heat may pass only by radiation to the nickel sleeve 7 where it is absorbed by the carbon coating and departs by conduction through the nickel sleeve 7 and the copper thimble 2 to the water circulating through pipes 11 and 16.

There is little heat transferred to radiation away from the discs 52 except at their inner edges. Radiation outward from the faces of the discs does not remove heat therefrom because they are adjacent to similar discs at substantially the same temperature. Any radiation from one disc is thus counteracted by an equal radiation from its neighbors. The uncoated discs at each end of the stack reflect heat toward the coated oven. Because they are uncoated they emit few electrons and if their temperature differs from that of the other discs no non-uniformity of current density results.

There is some radiation from the inner faces of the rings 53, but very little heat is delivered to or received from the discs 52 because of the radiation from the rings 53. This is partly because of the relative position of the surfaces, but principally because they are at substantially the same temperature. There is some heat radiated to the anode surface from the space between two adjacent discs. Probably this heat is substantially equal in amount to that radiated into such space by the inner faces of the rings 53.

Whatever the effect of the other portions of the radiation may be, the radiation from the inner edges of the discs accounts for substantially all of the heat departing from the discs. This is a small amount of heat because the radiation surface is small. The heat which departs from the discs at their inner edges is readily supplied by thermal conduction into the discs from the sleeve 24 and rings 53. There is good thermal connection over an ample surface at the outer edges of the discs. Moreover, the outer edge is greater than the inner edge so that the heat as it flows inwardly through the discs is traveling into a more restricted space. There is, therefore, very small difference in temperature between the two edges of any one disc.

There is no substantial disturbance of this practically uniform distribution of temperature by convection currents in the mercury vapor. This is partly because the mercury vapor being at a small pressure, there is very little of it to convey current by convection and partly because there are not sufficient open spaces in which convection currents could be set up.

Some heat travels lengthwise along the copper envelope 3. The thick part adjacent the stack of discs affords good thermal conductivity and so equalizes any irregularities of temperature in the cathode. Heat flows downwardly into the thinner ribbed part of the wall 3, but most of this is delivered into the nitrogen in the interior of the sleeve 58 by the ribs 57. Therefore, the thickened portion of the wall 3 below the ribbed part receives comparatively little heat and that which it does receive is removed by the water in the jacket 17. Consequently, the seals between

the copper and the glass are never dangerously heated.

Current is delivered to the anode through a lead connected thereto in any desirable way, such as by the clamp **105** on the lower end of the pipe **14**, and is led from the cathode by a lead connected to the connector **23**. If the potential is in the direction just indicated, the tube conducts current. If the potential is in the opposite direction, the tube is non-conducting because the electrons do not emerge because of the carbon coated anode.

Electrons which emerge from the discs **52** are directed toward the anode by the difference of potential between the copper wall **3** and its nickel lining **24** on one hand, and the sleeve **7** on the other hand.

Ionized mercury is present throughout the whole space between the cathode and the anode and adds to the conductivity of the tube by largely neutralizing the space charge. This effect occurs between neighboring discs **52** as well as between the anode and the inner edges of said discs. The tube, therefore, has good conductivity in one direction and almost zero conductivity in the other direction. One reason why the tube is practically non-conducting in the reverse direction is that the carbon coating on the anode has substantially no power to emit electrons and also destroys the power of any of the coating of the cathode which may be deposited on the anode. Sublimation of the oxide onto the anode or other transfer thereto does no harm.

The tube, therefore, is an efficient rectifier. Since the area of the cathode is large because of the many discs **52**, it is capable of delivering a large current to the anode without requiring any more current per square inch of cathode than heretofore.

It is desirable to plate all the copper parts both inside and outside of the tube with nickel whereever this is possible. Obviously the copper must not be plated where it is to be sealed into the glass.

In the form of my invention illustrated in Fig. 5 the operation is very similar. Electrons pass readily from the discs **82** to the disks **85** and this causes current to flow from the rod **84** to the copper envelope **81** but current does not flow in the opposite direction because the rod **84** and discs **85** are not coated with an electron-emissive substance. There being no mercury vapor in this tube, the space-charge effect is somewhat greater, and for that reason the anode is supplied with discs **85** closely spaced with the discs **82**.

The overlapping of discs **82** and **85** does not result in arcing even though they are very close together because of the absence of ionizable gas. The region where the discs **85** overlap the discs **82** is of small impedance because of the short distance and the large cross-section.

In the form illustrated in Fig. 6, the action is similar and need not be described in detail. The current flow is first from one anode and then from the other to the cathode.

The grids **96** have the purpose of controlling the discharge in a way made familiar by the so-called grid-glow tube. This action need not be described in detail.

They also have the function of acting as shields against radiation. Any radiation which passes through the holes in the outer member of either shield is reflected by the inner member so that the two members of a grid, taken together, constitute a substantially continuous reflecting shield. The grids are preferably made of bright nickel to assist in this purpose.

When the discharge is upward, the lower grid acts as a guard to prevent ionization between it and the lower anode. Similarly, when the discharge is downward, the upper grid prevents ionization between it and the upper anode. In this way, the grids prevent any accidental striking of an arc between the two anodes.

Certain features disclosed in this application are also disclosed in my application, Serial No. 407,690 filed Nov. 16, 1929 now Patent No. 1,997,693 of which this application is a continuation in part.

It is obvious that the particular forms of heater shown in connection with the several forms of tubes illustrated can each be applied to any of the forms of tubes. It is equally obvious that the grid illustrated in Fig. 6 can be applied to the other forms of tube except that shown in Fig. 5. It is also obvious that two anodes instead of one may be used in any form of tube illustrated.

It will be clear to those skilled in the art that many other variations in detail can be made without departing from the spirit of this invention, and the circumstance that only a few modifications have been illustrated and described is not to be construed as a limitation. What I intend to protect as my invention is indicated in the accompanying claims.

I claim as my invention:

1. A space-current device comprising an envelope separating the current-carrying space from the atmosphere, a cathode member constituting a portion of said envelope, means for heating said cathode member comprising a heating device in proximity to said member external to the envelope and a device for minimizing radiation from said heating device away from said envelope, said heating device and radiation minimizing device being separable from said envelope and means supporting said heating device and radiation minimizing device independently of said envelope.

2. An electronic device comprising an anode, a cathode having an opening into which said anode extends, an envelope enclosing said electrodes, means rigid with the envelope supporting the anode and means rigid with the envelope for maintaining the position of the anode transversely relative to said opening, said position-maintaining means permitting longitudinal movement of said anode.

3. A space current device comprising an envelope separating the current-carrying space from the atmosphere, a cathode, a portion of which is part of said envelope, coaxial elements electrically integral with said part of the envelope and constituting another portion of the cathode, an anode coaxial with said elements, a heater external to said envelope and adjacent to said part which is a portion of the cathode, means surrounding said heater for minimizing travel of heat outward, whereby the coaxial elements of the cathode have substantially the same temperature throughout their width.

4. A gaseous discharge device comprising an envelope having a portion of its wall consisting solely of metal which has a thermionic emissive interior surface, an anode extending within the interior of said wall portion, a gaseous atmosphere at low pressure within said envelope and an exterior electric heater for said wall portion.

5. A gaseous discharge device comprising an envelope having a portion of its wall consisting solely of metal which has an oxide coated ther-

mionic emissive interior surface, an anode extending within the interior of said wall portion and having a surface reacting with said oxides to minimize the thermionically emissive properties thereof, and an exterior electric heater for said wall portion.

6. A gaseous discharge device comprising an envelope having a portion of its wall consisting solely of metal which has a thermionic emissive interior surface, an anode extending within the interior of said wall portion, cooling means for said anode, and an exterior electric heater for said wall portion.

7. A gaseous discharge device comprising an envelope having a portion of its wall consisting solely of metal which has surfaces projecting inwardly therefrom and containing electron emissive material, an anode extending within the said wall portion and spaced from said projections a distance to receive electronic discharge therefrom, an exterior heater for said wall portion and projections, and means lessening the heat dissipated from the exterior surface of said wall portion.

8. A gaseous discharge device comprising an envelope consisting of a glass wall and a metal wall having surfaces projecting inwardly therefrom and containing electron emissive oxide material, an anode extending within said metal wall and surfaces and having a carbon surface thereon to react with said oxide to minimize the thermionically emissive properties thereof, said glass wall making a vacuum-tight seal connection between said metal wall and said anode, an exterior heater surrounding said metal wall and projecting surfaces, and means for minimizing the dissipation of heat energy from the exterior wall of said metallic wall portion.

9. An electrical discharge device comprising an envelope having a metallic wall portion having an electron emissive surface within said device, an electric heater therefor on the exterior of said device, cooling means lessening heat transference from the heated metallic wall portion to the remaining portions of said envelope, an anode extending within said metallic wall portion and electron emissive surface and cooling means for said anode distinct from said first mentioned means.

10. A gaseous discharge device comprising an envelope consisting of a glass wall and a metal wall, an anode within said envelope, surfaces containing electron emissive oxide material projecting from said metal wall and extending about said anode, said glass wall making a vacuum-tight seal connection between said metal wall and said anode, a heater surrounding said metal wall and projecting surfaces, and means confining heat energy within said metal wall and surfaces.

11. An electronic device having a composite metal and glass wall and containing a cathode comprising a plurality of closely-spaced parallel sheet members having arcuate outer and inner edges and a member connected to the arcuate outer edge of said members which is coextensive with the entire thickness of said metal wall, the inner edges of said members being free, said cathode having a thermionically-emissive coating, means for heating said cathode, and an anode within the region subtended by the curve of the arcuate outer edges of the sheet members, said anode spaced a distance from the inner edges to receive electronic discharge from said inner free edges and a source of heat surrounding said member connected to the arcuate outer edges.

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