July 2, 1940. P. L. SPENCER ET AL 2,206,271

ELECTRICAL SPACE DISCHARGE DEVICE

Original Filed June 5, 1934 3 Sheets-Sheet 1

Fig. 1

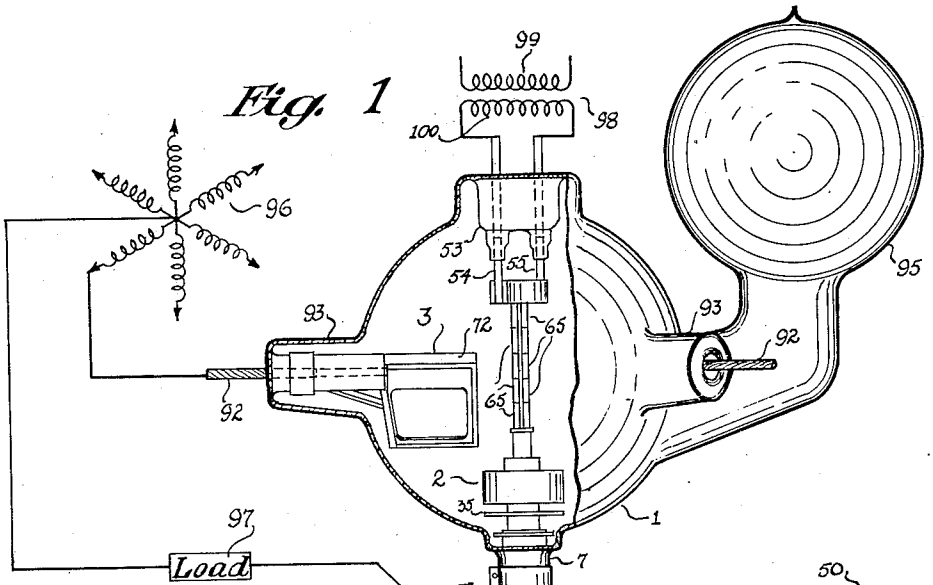


Fig. 2

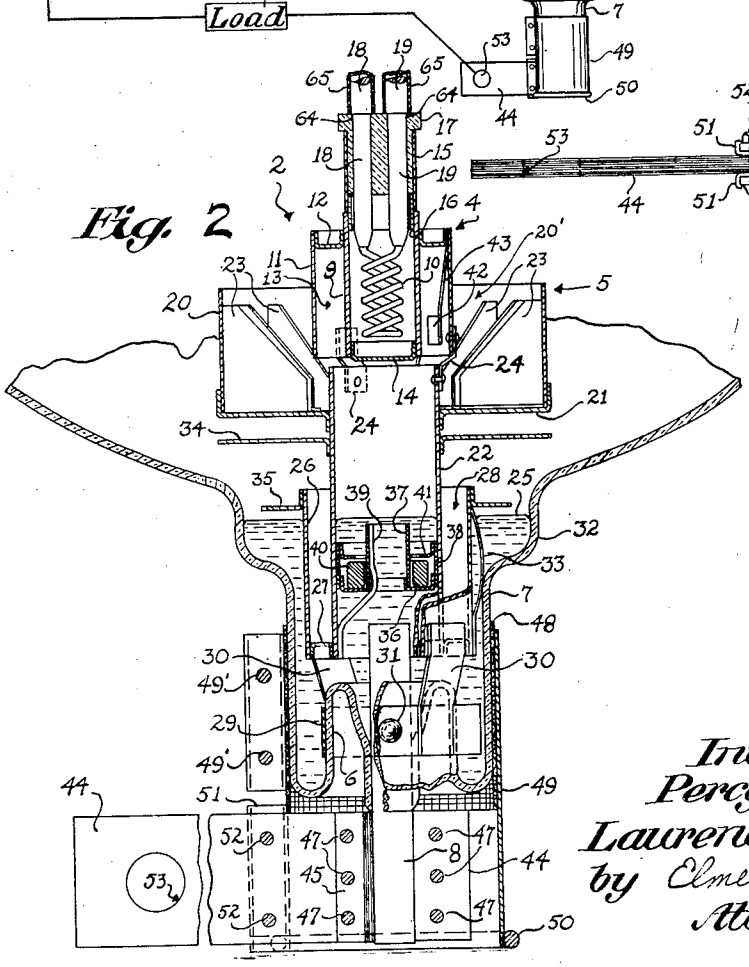
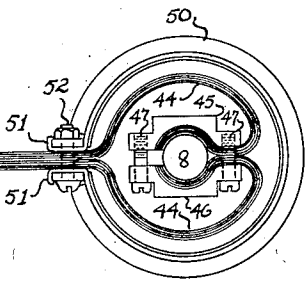


Fig. 3



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Fig. 4

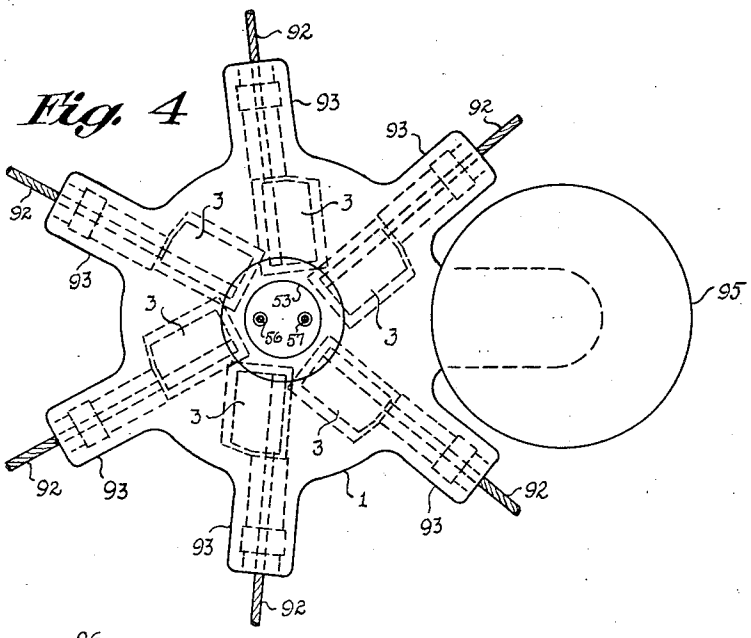


Fig. 5

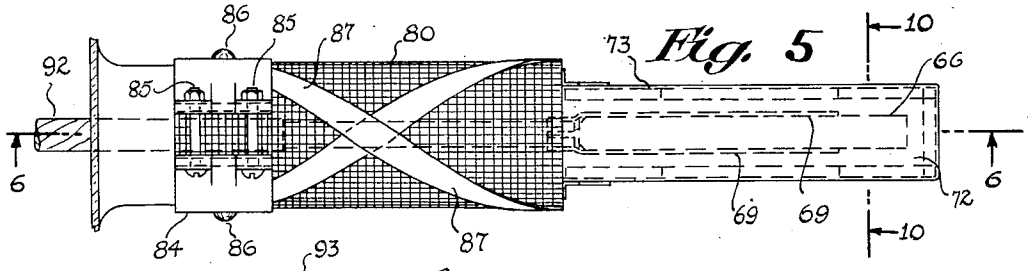
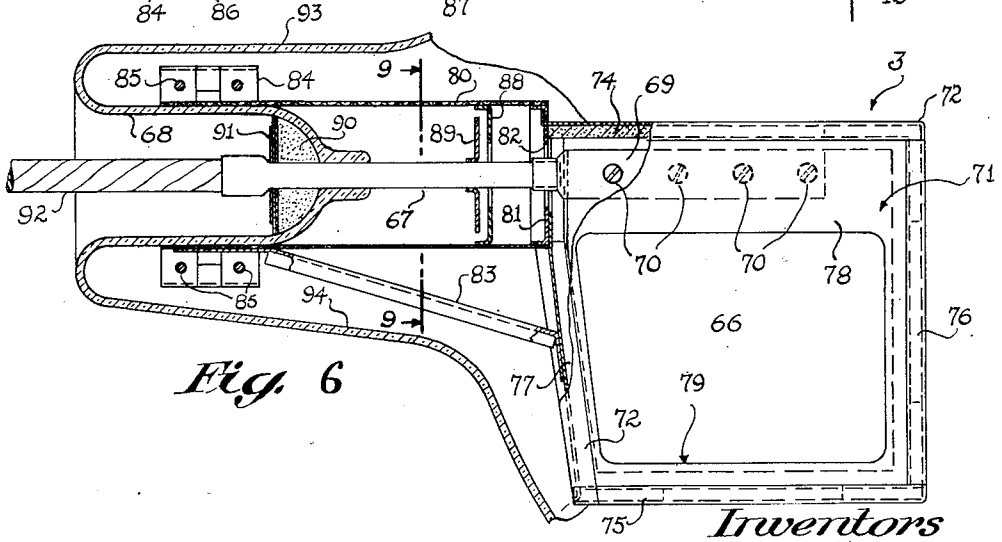


Fig. 6



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Fig. 7

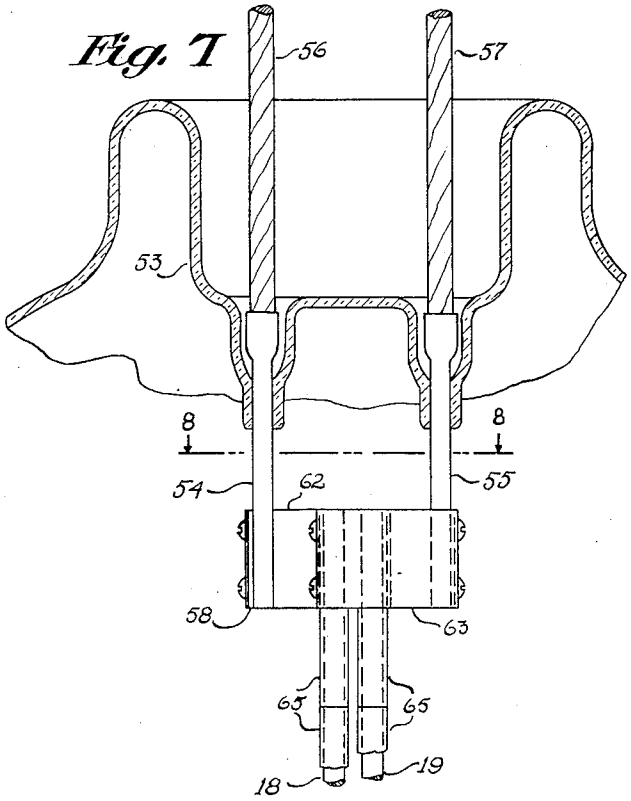


Fig. 8

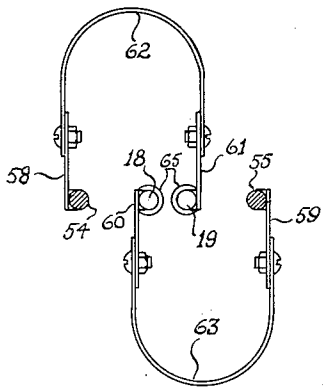


Fig. 9

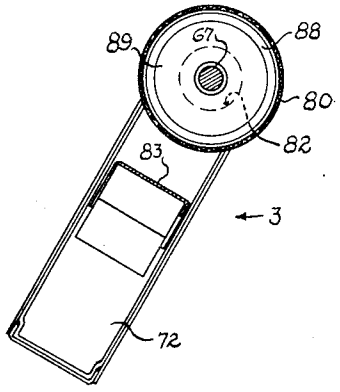
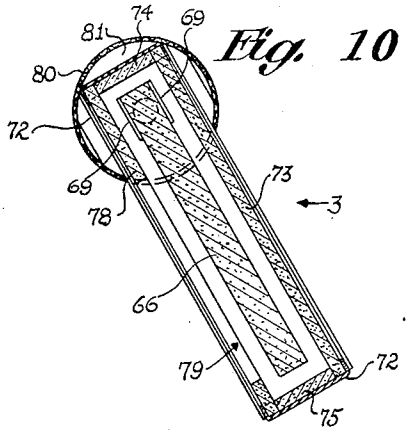


Fig. 10



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UNITED STATES PATENT OFFICE

2,206,271

ELECTRICAL SPACE DISCHARGE DEVICE

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Application June 5, 1934, Serial No. 729,101
Renewed May 8, 1939

27 Claims. (Cl. 250—27.5)

This invention relates to electrical space discharge devices capable of carrying high values of current.

One of the objects of the present invention is to produce a cathode for such a device having a low voltage drop and a long life.

Another object is to enable the device to be started safely after little or no preliminary heating of the cathode.

Still another object is to produce a device accomplishing the above object, having a simple and rugged construction.

The foregoing and other objects of the invention will be best understood from the following description of an exemplification thereof, reference being had to the accompanying diagrammatic drawings, wherein:

Fig. 1 is a vertical elevation on a reduced scale of the novel tube, with the envelope broken away, said tube shown connected to one type of circuit in which it may be used;

Fig. 2 is a vertical cross-section of the lower part of the tube shown in Fig. 1 and particularly of the novel cathode shown approximately full size;

Fig. 3 is a bottom view of the lower end of the structure as shown in Fig. 2;

Fig. 4 is a top view of the tube as shown in Fig. 1;

Fig. 5 is a top view of one of the anode assemblies shown approximately full size;

Fig. 6 is a cross-section taken along line 6—6 of Fig. 5;

Fig. 7 is a vertical cross-section of the upper part of the tube shown in Fig. 1 approximately full size;

Fig. 8 is a cross-section taken along line 8—8 of Fig. 7;

Fig. 9 is a cross-section taken along line 9—9 of Fig. 6; and

Fig. 10 is a cross-section of the anode structure taken along line 10—10 of Fig. 5.

Space discharge devices of the type having a thermionic cathode operating with a filling of some suitable vapor require special precautions in their starting and operating. Such devices designed to carry fairly large amounts of current heretofore have utilized a cathode having a comparatively large surface coated with electron-emitting oxides, and provided with a separate heating filament. In such devices precautions have to be taken to prevent the current density on the cathode surface from rising above a certain value, and also to prevent the cathode from getting too hot at any portion of its surface. If, for example, the current is allowed to increase beyond the normal current density so as to approach concentrated arc intensities, the coating is soon disintegrated and removed from the cathode surface. The disintegration of the coating produces deleterious gases, and the denuding of the cathode surface of its coating soon terminates the useful life of the device. The permissible current density on the cathode depends to some degree on the vapor pressure around the cathode, and the distribution of the current over the cathode surface depends to a large degree on the fact whether or not the entire emitting surface is above a predetermined minimum temperature. Thus in starting, the heating current for the cathode has to be turned on for a long period so as to make sure that the entire coated emitting surface of the cathode is above the required minimum, and also to insure that the entire tube is warmed to the proper temperature so as to maintain the requisite vapor pressure within the device. These precautions necessitate a long preliminary heating period in discharge tubes of any considerable current rating. Also during the operation of the device, the current through the device cannot be permitted to rise above a predetermined maximum even for an instant inasmuch as such a current surge would immediately destroy a portion of the coating, which in turn would soon terminate the useful life of the cathode.

In accordance with the invention, a cathode has been constructed which can be operated without such coatings as were heretofore used, and furthermore which can be subjected to enormous overloads for short periods of time without adversely affecting the operation of the tube. With such a cathode it has been found that only a limited portion of the cathode need be heated to its starting temperature, and the vapor pressure within the device need not be very great in order that the tube be safely started. Thus the heating current is merely turned on for a short period after which the tube is ready to start. If upon starting the current localizes as an arc upon a limited portion of our cathode, the adjacent portions of the cathode are quickly heated to temperature of electron emission and the current distributes itself over the operating surfaces of the cathode. Also if the vapor pressure is not great enough to cause a low voltage drop, the heat liberated by the cathode drop soon raises the vapor pressure to the proper value. As has been stated, localized arcs of great current intensity can occur on limited portions of my

cathode without adversely affecting the operation thereof, and thus in starting or running, the localization of the arc upon the limited heated portion of the cathode for a short period is permissible.

The form of the invention as shown in the drawings is a rectifier consisting of an evacuated envelope 1 of some suitable material such as glass. This envelope contains a cathode structure 2 and one or more anode structures 3. The cathode structure consists of a primary cathode 4 and a secondary cathode 5. The cathode structure 2 is supported from a reentrant stem 6 in an extension 7 formed in the lower side of the envelope 1. Through the center of the stem 6 is sealed a cathode lead-in conductor 8. This lead-in conductor may be made of some suitable material, such as tungsten, and the glass of the stem may be made of a borosilicate glass, such as Pyrex.

The primary cathode 4 consists of a hollow tubular member 9 containing a heating filament 10. The member 9 is surrounded by a tubular member 11, which is connected to the upper end of the tubular member 9 by means of an annular closing member 12. The members 9, 11 and 12 provide a hollow cathode chamber 13. The lower end of the tubular member 9 is closed by a cap 14, and has a tubular extension 15 connected to its upper end. The connection between the extension 15 and the tubular member 9 may be made by a sleeve 16 welded to each of these members. The upper edge of the sleeve 16 forms a stop for the insulating plug 17 which fits into the upper end of the tubular extension 15. The insulating plug 17 is provided with two longitudinal holes through which extend the conductors 18 and 19 which form the current supply leads for the heating filament 10. This heating filament may be formed in the shape of a double helix, the two ends of which are connected to the lower ends of the conductors 18 and 19. During the operation of the device the tubular member 9 becomes hot, and therefore should be formed of a refractory material, such as tantalum, tungsten or molybdenum. The annular members 12, 14 and 16 likewise should be formed of a similar refractory material. The member 11 being subjected to a somewhat lower temperature during operation than the member 9, may be formed of a somewhat less refractory material, although such materials as mentioned above are preferably used. The heating filament 10 may be of tantalum, tungsten or the like, while the conductors 18 and 19 may be of molybdenum. The insulating plug 17 may be of some suitable insulating material, such as magnesia.

The secondary cathode 5 consists of a cylindrical member 20 closed at its lower end by a cap 21, thus forming a hollow cathode chamber 20'. Both members 20 and 21 may be formed of nickel inasmuch as the temperature to which they are subjected during operation of the device is considerably less than that to which the primary cathode is subjected. The cap 21 is provided with a central opening through which the upper end of a tubular conduit 22 extends. These two members may be rigidly connected together as by welding. The tubular conduit 22 likewise may be formed of a refractory material, such as molybdenum. The secondary cathode is also provided in its hollow cathode chamber 20' with a set of fins 23 also formed of nickel and welded in place within the tubular member 20. These fins may be spaced radially within the cylindrical member 20, and shaped as indicated in Fig. 2 so as to present spaces between these fins to the opening which exists between the lower end of the primary cathode 4 and the upper end of the tubular conduit 22. The secondary cathode 5 not only serves as a cathode member, but by surrounding the primary cathode 4 in the manner shown acts as a heat shield for the primary cathode 4 and prevents excessive loss of heat from said primary cathode. The fins likewise act as heat shields for each other, and prevent excessive loss of heat.

The members 11 and 22 are electrically and mechanically connected together by means of straps 24 which may be riveted to the upper end of the conduit 22 and the lower end of the tubular member 11. The conduit 22 which conducts vapor from the pool 25 to the interior of the cathode structure, is provided with a heat-insulating arrangement around its lower end. This heat-insulating arrangement consists of a tubular shielding member 26 surrounding and spaced from the conduit 22. The lower ends of the shielding member 26 and the conduit 22 are mechanically connected by means of an annular member 27 which closes the space between the shielding member and the conduit, and prevents the material of the pool 25 from rising into the space between said members. In this manner an evacuated space 28 exists between the conduit 22 and the shielding member 26, which effectively prevents the loss of excessive heat across such a space. The cathode structure is supported in place on the stem 6 by means of a clamping strap 29 which is clamped around the stem 6 and carries two supporting arms 30 welded at their lower ends to the clamping strap 29 and at their upper ends to the lower part of the heat shield 26. The stem 6 has formed on one side thereof a glass bead 31 which engages with an aperture in the clamping strap 29, and effectively holds the clamping strap 29 in place in the stem 6. The upper end of the extension 7 is provided with a cup-shaped enlargement 32, and the entire extension 7 and most of the cup-shaped enlargement 32 are filled with the pool 25 of some easily vaporizable material for supplying an atmosphere of ionizable vapor to the envelope 1. The use of mercury as the vapor-supplying material is preferred. The enlargement 32 permits relatively large amounts of mercury to be evaporated with a relatively small change in the level of the mercury pool. It will be seen that the mercury pool extends partly up inside the conduit 22 and also around the heat-shielding member 26, but does not extend into the space 28. In order to steady the cathode structure within the extension 7, the heat shielding member 26 may be provided with a number of leaf springs 33 fastened at their lower end to the end of the heat shield 26. In placing the cathode structure within the extension 7, these leaf springs engage the sides of the extension 7 and resiliently resist lateral motion of the entire cathode structure within the extension 7. In order to prevent excessive radiation of heat from the secondary cathode member onto the lower end wall of the envelope 1 as well as the upper portion of the mercury pool, an additional heat shield 34 is fastened to the conduit 22 and spaced from the lower side of the cap 21. In order further to shield the upper side of the mercury pool 25 from receiving excessive amounts of heat from the structures above it, the upper end of the heat shield 26 is provided with a shielding plate 35 which

projects over the upper surface of the mercury pool 25.

Cathode metallic surfaces will emit large numbers of electrons at comparatively low temperatures if an activating agent, such as alkali or alkaline earth metal, is deposited upon these surfaces. Since both of these metals are useful, we will use the term "alkaline metal" hereafter in the specification and claims to cover both alkali metal and alkaline earth metal. In the particular embodiment described, barium in metallic form is preferably used as the activating agent. During operation, barium so deposited would be driven off the surface of the cathode in a comparatively short time. This is due to the fact that at the temperature of electron emission, there is considerable vaporization of barium and also the cathode may be subjected to positive ion bombardment which tends to dislodge any layer of barium on the cathode. This difficulty is overcome, however, by continuously depositing upon the active cathode surfaces metallic barium so as to renew the supply of metallic barium thereon.

In order to supply the requisite amount of barium in the device, an annular cup constructed of a washer 36, an inner sleeve 37, and an outer cylinder 38, all made of nickel, is mounted within the conduit 22. The members 36, 37 and 38 are secured together, as, for example, by welding, and the assembly is retained within the conduit 22 by means of a supporting wire 39 welded at one end to the conduit 22 and at the other end to the cylinder 37. Within this annular cup a washer 40 of barium is placed, and retained in place by an upper washer 41, also preferably made of nickel. The central opening in this washer is larger than the sleeve 37 so that mercury may enter the annular cup, amalgamate with the barium 40, and the amalgam so formed can pass out into the larger body of mercury within the lower portion of the tube. By thus forming an amalgam of mercury and barium, barium will be continuously conveyed to the cathode surfaces during operation, as will be explained below.

During the processing involved in the manufacture of the tube, it is desirable to have a sufficient amount of barium initially on certain of the cathode surfaces. This is preferably accomplished by first heating the pool 25, whereby sufficient material is vaporized from said pool to carry enough barium up onto the cathode to enable easy initial starting to occur. Instead of supplying the barium in this way, a tab 42 may be mounted within the cathode chamber 13, which tab is wrapped around a small amount of barium and supported within said chamber by means of an arm 43. The tab and arm being within the portion of the cathode which reaches a fairly high temperature during operation are preferably formed of a refractory material, such as described above. Instead of using the barium within the tab 42 for the initial starting of the tube, a light coating of electron-emitting oxides may be placed on the tubular member 9. When the tube is first started, these oxides are soon disintegrated and removed from the cathode surface. The deleterious gaseous products of this disintegration are pumped out, leaving no material within the tube which during operation disintegrates and liberates deleterious gases. By the time the oxide coating on the member 9 is destroyed, the action of the tube will have deposited sufficient barium on the cathode to take care of the subsequent starting and running of the tube. In most cases, however, both the barium within the tab 42 and the initial light coating on the member 9 may be omitted, and the barium supplied to the cathode, as stated in the first part of this paragraph.

The lead-in conductor 8 being in contact with the mercury in the pool 25, which in turn is in intimate contact with the cathode structure, thus is electrically connected to the cathode and serves to conduct current from the cathode to the exterior of the device. The large amounts of current which conductor 8 carries tend to heat said conductor. However, the mercury in contact with the conductor 8 rapidly conducts this heat away and keeps the conductor 8 cool. The heat thus conveyed to the mercury pool vaporizes some of the mercury, and aids in the operation of the tube. Since in handling the tube there is a possibility of the lower end of the lead-in conductor 8 being subjected to shocks and thereby fracturing the seal, it is desirable to protect the lead-in conductor 8 so that the possibilities of such shocks being transmitted to said lead-in conductor are eliminated. In order to do this, connection is made to the conductor 8, as shown most clearly in Figs. 2 and 3. Around the lower end of said lead-in conductor is clamped a number of flexible leaf copper strips 44 by means of a pair of clamping blocks 45 and 46. These blocks press the ends of the copper strips 44 into intimate contact with the lead-in conductor 8 by a number of clamping screws 47. Around the lower end of the tubular extension 7 is wrapped a metallic screen 48 about which is clamped the tubular clamping member 49 by means of clamping bolts 49'. The lower end of this clamping member 49 projects beyond the lower end of the tubular member 7 and is reinforced by a ring 50 welded to the lower end of the clamping member 49. The copper strips 44 are looped around the lead-in conductor 8 in the manner shown in Fig. 3, and are in turn securely fastened to the lower end of the clamping member 49 by passing between the two clamping members 51, which are clamped onto the copper strips 44 by means of a number of bolts 52. The outer end of the bundle of copper strips 44 is provided with an opening 53 so as to facilitate connection to an external conductor. Any strain put upon the conductors 44 or the member 49 is transmitted to the comparatively heavy wall of the tubular extension 7, and thus the seal is effectively protected.

At the upper end of the envelope is formed a reentrant stem 53 through which are sealed the lead-in conductors 54 and 55 for the filament current supply conductors 18 and 19. The lead-in conductors 54 and 55 are preferably formed of tungsten or molybdenum, and the glass of the seal surrounding them is preferably a borosilicate seal glass. To the outer ends of the lead-in conductors 54 and 55 may be connected flexible conductors 56 and 57, whereby external connections to said conductors may easily be made. The connection between the lead-in conductors 54 and 55 and the current supply conductors 18 and 19 is preferably flexible in order to relieve the lead-in conductors 54 and 55 from as much strain as possible. Due to this flexible connection, the weight of the cathode structure is supported by the lower portion of the cathode 1, and any unusual expansion between the walls of the glass envelope 1 and the cathode structure and its lead-in conductors is taken up by said flexible connection. This connection is made as follows. To the lower ends of the lead-in conductors 54 and 55 are welded connection plates 58 and 59, respectively. Also to the upper

ends of the current supply conductors 18 and 19 are welded connection plates 60 and 61, respectively. A laminated U-shaped connector 62 is bolted to the connector plates 58 and 61, thus interconnecting the lead-in conductor 54 and the current supply conductor 19. A similar connector 63 interconnects the lead-in conductor 55 and the current supply conductor 18. The connectors 62 and 63 are sufficiently resilient so that excessive strains cannot be transmitted to the lead-in conductors 54 and 55. However, these connectors are sufficiently rigid so that some steadying action is exerted by them upon the cathode structure. This steadying action is increased to some degree by forming shoulders 64 at the lower ends of the current supply leads 18 and 19, which shoulders engage the upper surface of the insulating bushing 17. In order to prevent a discharge occurring between the current supply conductors 18 and 19, we surround these conductors by a number of insulating tubes 65. These tubes are made of some refractory insulating material, such as magnesia. It is not necessary to cover the lead-in conductors 54 and 55 or the connectors 60 and 61 inasmuch as these members are sufficiently removed from the cathode structure so that their temperature is low enough to prevent a discharge from occurring between them at the comparatively low voltage applied thereto.

Each anode structure consists of an anode 66 which is made of graphite in the form of a flat plate. Inasmuch as the structure is very compact, these is comparatively little space for the anodes. The amount of current which each anode can safely carry depends upon the anode area over which the current can be distributed and the maximum temperature which the anode reaches. This temperature depends in turn upon the amount of anode material and the amount of heat which the anode can radiate. By making the anodes in the form of flat plates, they are provided with the maximum amount of current-carrying and radiating surface for the amount of anode material available. The anode 66 is supported from an anode lead-in conductor 67 made preferably of tungsten and sealed through one end of a reentrant stem 68. The outer end of the lead-in conductor 67 is connected to a flexible conductor 92, whereby external connections may be readily made to the anode. The connection between the lead-in conductor 67 and the anode 66 is made through a pair of clamping connectors 69 which are welded at one end to the inner end of the lead-in conductor 67. A plurality of screws 70 securely fasten both connectors 69 to opposite sides of the upper end of the anode 66.

In order to shield the anode 66, it is surrounded with a shielding structure 71. This shielding structure consists of a metal frame 72, built up of thin nickel members. This metal frame supports a graphite box which completely surrounds the anode 66 except for one or more discharge openings in one side of said box. This box consists of a solid back plate 73, a top plate 74, bottom plate 75, end plates 76 and 77, and a front plate 78. Each one of these plates is formed of graphite. The front plate 78 may be formed with a discharge opening 79 which permits the discharge to pass from the anode 66 to the cathode. Thus it will be seen that every surface of the shield exposed to the anode 66 is composed of graphite. Graphite absorbs radiated heat readily, and in turn rapidly re-radiates the heat. Thus the graphite shield enables the heat generated at the anode to be readily dissipated. Graphite at the temperature at which the shields operate has practically no electron emission, which if it occurred might adversely affect the shielding action. The shielding structure 71 is supported from the reentrant stem 68. Around said reentrant stem is placed a cylinder 80 formed of some suitable metal gauze, preferably nickel. This cylinder is closed at one end by a plate 81 welded thereto, said plate having a relatively small opening 82 through which the conductor 67 passes. The plate 81 is securely fastened to the metal frame 76 of the shielding structure 71, as, for example, by being welded thereto. The cylinder 80 being formed of metal gauze does not have in itself sufficient rigidity to satisfactorily support the shielding structure 71. Therefore, a stay member 83 welded at its lower end to a portion of the metal frame 76 and at its upper end to the cylinder 80, is used. The cylinder 80 and stay 83 are firmly clamped around the reentrant stem 68 by means of the clamping member 84. This clamping member is made of a nickel steel alloy having a coefficient of expansion which is not greater than that of the glass in the stem 68. This insures that the clamp cannot loosen on the stem 68 during operation of the tube. Clamping bolts 85 are used to tighten the clamping member 84 around the cylinder 80 and stay 83. The reentrant stem 68 is provided with several integral projections 86 which project through openings in the clamping member 84, and prevent any relative rotation between the shielding structure 71 and the reentrant stem 68. In order to increase the rigidity of the metal gauze cylinder 80, there is welded across the upper side thereof two nickel strips 87 formed into an X-shape. One end of said X is firmly retained in place under the clamping member 84, and the other end thereof is welded to the cylinder 80 cnto the plate 81.

In the seal between the conductor 67 and the reentrant stem 68, the glass is preferably a borosilicate seal glass. The seal is protected by packing the inside of the reentrant stem 68 with finely-powdered metallic particles 90, which particles are held in place by retaining members 91. This seal and the manner in which it operates is more completely described in the co-pending application of James D. Le Van, Serial No. 589,180, owned by the assignee of the present application. In order to protect the seal against damage, it is desirable to keep it as cool as possible. For this reason the cylinder 80 is made of metal gauze in order to allow any heat liberated near the seal to readily escape therefrom. Also any mercury vapor which enters the space within the cylinder 80 is allowed to escape therefrom without accumulating therein. In this way there is very little or no tendency for a discharge to occur to the lead-in conductor 67 at its sealing point. To further protect the seal from overheating, heat generated at the anode 66 is prevented from being radiated back onto the seal through the opening 82 by interposing barrier members 88 and 89 between the anode and the seal. The barrier member 88 is a ring fastened to the cylinder 80, and the barrier member 89 is a plate fastened to the lead-in conductor 67. Each reentrant stem 68 carrying its respective anode structure is mounted within an extension 93 formed integrally with the glass envelope 1. This projection 93 is formed with a slanting lower wall 94, whereby mercury which condenses in this projection 93

runs back into the mercury pool. It will be noted that in the embodiment which is shown the rectifier is illustrated as being provided with six anodes. Thus the tube 1 is formed with six projections 93 disposed about the central portion of the envelope 1.

Each of the anode structures is disposed within the envelope 1 at an angle, as indicated in Figs. 9 and 10. The anode face opposite the opening 79 in the anode shield is directed downwardly toward the cathode. Thus each anode structure presents to its adjacent anode face only the solid rear graphite plate of its shielding structure. The only discharge path, therefore, which can exist between anodes is an indirect one. These shielding members effectively prevent discharges between anodes despite the fact that the anodes are closely spaced within the envelope 1. Due to the position of each anode within the tube, any vapor which condenses on the walls of the envelope 1 and falls therefrom cannot fall upon the face of the anode presented to the discharge opening 79. The only anode structure surface upon which such material can fall is the solid graphite surface of the shielding structure 71.

In order to provide sufficient surface for condensing the vapors from the pool 25, the tube 1 is formed with a condensing chamber 95. This condensing chamber is sufficiently removed from the cathode structure and from the path of the discharge so that its temperature can be maintained at any desired value and is substantially unaffected by the temperature of the region surrounding the cathode.

The tube which has been described may be connected in any suitable manner to a rectifying circuit. For example, in Fig. 1 the tube is shown connected to a six-phase rectifying circuit. The secondary of a transformer is represented at 96, said secondary having six-phase windings. The primary of the transformer (not shown) may be connected in any suitable manner to a plural-phase A. C. power line. One of the anodes 66 is illustrated as being connected to one end of one of said phase windings. Each of the other phase windings is in turn connected to each one of the other anodes. The neutral point on said secondary 96 is connected through some suitable load 97 to the cathode lead-in connector 44. The heating filament 10 may be energized by some suitable means, such as, for example, a filament transformer 98 having a primary winding 99 connected to a source of alternating current, and the secondary source 100 connected to the two lead-in conductors 54 and 55.

In constructing the novel tube, first of all the various elements are assembled, as shown in the drawings. Mercury is then introduced to the level indicated in Fig. 2. The exterior of the tubular extension 7 is then heated and a considerable amount of mercury is vaporized which condenses upon the walls of the envelope 1. This preliminary vaporization of mercury is carried on so that when barium is released from the cathode structure and condenses upon the walls of the tube 1, it will amalgamate with the mercury already there, which amalgam may pass readily back into the pool 25. Thus excessive deposits of barium upon the glass walls are effectively prevented. The mercury pool is also heated sufficiently to drive out from both the mercury pool and the barium washer occluded gases. During this heating process a considerable amount, if not all, of the barium amalgamates with the mercury, thus leaving a mixture of mercury and barium in the pool 25. During the preliminary treatment of the tube, an intense discharge is allowed to pass to various elements within the tube, thus raising them to a comparatively high temperature and driving off all occluded gases. During this portion of the treatment, the tube is connected to an exhaust pump, and these gases are removed therefrom. After the tube has been de-gasified in this manner, it will be noted that there are no elements which can decompose and liberate deleterious gases in the tube during operation thereof. This feature tends to produce a very long life of the tube.

In accordance with the present understanding of the invention, the theory of operation of the tube is as follows. When the filament transformer 98 is energized, a heating current flows in the heating filament 10, and quickly raises the tubular member 9 and the interior of the cathode chamber 13 to an operating temperature. During the preliminary de-gasifying of the tube, sufficient barium will have been liberated either from the tab 42 or from the pool 25 so that the walls of the cathode chamber 13 have deposited thereon a layer of barium. At the temperature to which the cathode chamber 13 is raised by the heating filament 10, the cathode surfaces carrying the barium emit large numbers of electrons. As stated above, the heating time need merely be long enough to heat the cathode chamber 13 or the member 9 alone to this emitting temperature. The secondary 96 may be energized at the same time as the filament, and voltage is applied between the cathode and each of the anodes. The electrons emitted from the cathode chamber 13 pass toward any anode that is positive and ionize the mercury vapor within the cathode chamber 13 as well as in the space between the anode and the cathode. In this way an arc-like discharge is started between the cathode and the anodes. The heat liberated by this discharge and also the heat liberated by the heating filament 10 passes down both by radiation and by conduction through the conduit 22 to the mercury within said conduit. This heat vaporizes large quantities of mercury which pass up through the conduit, and create a high density of mercury vapor within the cathode chamber 13. This vaporized mercury passes out through the opening between the hollow member 11 and the upper end of the conduit 22, and creates a high density of vapor around the fins 23 within the secondary cathode chamber 20'. The mercury vapor then passes out into the envelope 1 and condenses on the walls thereof and upon the walls of the condensing chamber 95. Thus low density of mercury vapor is adjacent the anode structures 3 and is determined largely by the temperature of the condensing chamber 95 and the cooler portions of the walls of the envelope 1. This condition of high density of mercury vapor adjacent the cathode surface and low density of vapor adjacent the anode surfaces is conducive to effective rectifier action.

It has been found that while large quantities of mercury are being vaporized from the pool 25, barium is carried up onto the cathode-emitting surfaces. It is believed that the mechanism whereby the barium is carried up onto the cathode-emitting surfaces may consist of a number of phenomena or a combination of two or more of these phenomena. During the operation, the mercury within the conduit 22 may be agitated rapidly, and due to the presence of the inner sleeve 37, whereby a restriction occurs within the

conduit 22, percolation of the mixture of barium mercury amalgam within the pool 25 may take place. Due to this percolating action, particles of barium mercury amalgam are forcibly thrown from the surface of the pool 25, and are carried by the vapor stream to the cathode surfaces. These particles not only deposit upon the surface of the member 9 and inner surface of the tubular member 11, but pass out and are deposited onto the surfaces of the secondary cathode 5. The mercury may be vaporized at such a rate that the level thereof falls below the surfaces of the members 36, 37 and 38. These members thereupon intercept the heat radiated and conducted from the cathode structure, and become quite hot. Mercury condensing in the tube and returning to the pool 25 forces the amalgam to rise above the upper end of the cylinder 37 and drop onto these hot surfaces. This amalgam is then heated rapidly and particles of barium mercury amalgam are thrown off from these surfaces, thus causing barium mercury amalgam to be deposited upon the cathode surfaces as described above. In addition to the actions which have been described, the mercury vapor may come off from the surface of the pool 25 within the conduit 22 with sufficient rapidity to carry with it small mist particles of the amalgam. The rate at which the vapor travels up through the conduit 22 may be sufficient to carry these mist particles along with it and deposit them on the cathode surfaces. Since large quantities of mercury are evaporated from and returned to the pool 25 and a small portion of barium may vaporize at the same time and deposit on the cathode surfaces, this continuous action may eventually deposit adequate quantities of barium on the cathode for proper operation. Thus it will be seen that during the operation with the tube there is a continual deposit of barium or mercury barium amalgam upon the cathode surfaces. These surfaces are sufficiently hot so that the mercury of the amalgam is quickly vaporized therefrom, leaving residual barium. The temperature which the cathode surfaces reach is sufficiently low so that barium can remain on these surfaces for a considerable period of time. The temperature is, however, sufficiently high so that the cathode surfaces carrying barium emits large amounts of electrons and enable the currents of large magnitudes to be drawn from the cathode. For example, cathodes have been made approximately the size as shown in the drawings from which over one thousand amperes have been drawn without adversely affecting the cathode.

The continual deposit of barium on the cathode surface renews the emitting surface of the cathode indefinitely. It also permits heavy temporary overloads to be drawn from the cathode without adversely affecting either the operation or the life of the cathode. The normal vaporization of barium from the cathode surface and the dislocation of barium by positive ion bombardment during operation are more than compensated for by the constant supply of barium to the cathode. If excessive amounts of current are drawn for a short time from the cathode, much larger quantities of barium may be dislodged from the cathode surfaces. However, the barium so dislodged is immediately replaced by a fresh deposit. Thus heavy surges of current which would denude an oxide-coated cathode of its active coating does not harm the present cathode. If, for example, an intense arc were to localize on the surface of the cathode, the barium at the localized spot would be soon driven off. However, if this occurred, the voltage drop at this point would go up and the arc would have a tendency to spread to adjacent portions of the cathode having a layer of barium. The area denuded of barium by the localized arc would immediately receive a fresh deposit of barium. It will be seen, therefore, that the novel cathode which has been devised is a thermionic cathode with a self-renewing surface.

The particular arrangement utilizing a vaporizable material, such as mercury, which is liquid at ordinary temperatures and an activating agent, such as barium, which is solid at ordinary temperatures, performs an additional function. Ordinarily if barium were placed upon a cathode surface and driven off, due to the relatively high temperature of the cathode and the bombardment by positive ions, this barium would condense upon the walls of the tube. At the usual temperatures at which tubes of this kind are operated, barium is solid. Therefore, in such an arrangement, the barium would collect upon the walls of the envelope and there would be no way whereby such barium could be returned to the surface of the cathode. However, by utilizing mercury which is liquid at the usual temperatures at which such tubes are operated, the mercury will amalgamate with the barium which tends to deposit on the walls of the tube, and this amalgam is sufficiently fluid so that it runs back into the pool 25. Thus the mercury serves not only to supply an ionizable vapor in order to carry the discharge, but also acts as a carrier for the barium, whereby the barium is carried from the pool to the cathode and then from the walls of the envelope back to the said pool.

As has been pointed out above, the discharge initially starts from the primary cathode chamber 13. This discharge passes out from the lower end of the tubular member 11 and past the surfaces of the secondary cathode 5 on its way to the anodes. This discharge quickly heats the surfaces of the secondary cathode to a high temperature so that the discharge instead of continuing within the primary cathode chamber 13 distributes itself over the surface of the fins within the secondary cathode chamber 20'. It is generally considered that in any cathode there is certain maximum density of current which can be drawn without increasing the cathode drop, and thus sufficient area of cathode-emitting surface must be provided in order to enable this maximum current density to exist at the highest currents which may be drawn from the cathode. However, at smaller values of load the current can safely be drawn from a smaller cathode area. In the cathode described, the area which emits electrons automatically adjusts itself so that the optimum current density exists on the emitting surfaces of the cathode. For example, when a small discharge is drawn to the anodes, less heat is liberated at the cathode and only a small portion of the secondary cathode 5 adjacent the primary cathode 4 is heated to its emitting temperature. Thus only a portion of the secondary cathode 5 emits electrons, but the amount of electrons so emitted is sufficient to carry the current. As more current is drawn from the cathode, more heat is liberated in the discharge, and a larger surface on the secondary cathode 5 is raised to its emitting temperature. Finally, at the maximum current which is drawn from the cathode, the entire inner surfaces of the

hollow secondary cathode 5 are at emitting temperatures and the current is distributed over all of these surfaces. As has been previously pointed out, the secondary cathode 5, due to the continual deposit of barium on it, has a self-renewing emitting surface as well as the primary cathode 4.

Tubes of the kind which have been described have a low voltage drop. For example, some tubes have been constructed in which the drop is consistently eight volts and in some instances the drop is much less. Also the life of the tube is extremely long. Such tubes have been constructed which have been operating for over three thousand hours continuously and carrying hundreds of amperes of rectified current.

This invention is not limited to the particular details of construction, materials and processes described above. For example, instead of using mercury vapor as the gaseous atmosphere within the tube, other vapors or gases could be utilized. Also the novel cathode shown herein could be utilized in other types of devices, such as gaseous discharge lamps and the like. Various other equivalents of these and other features of the invention will suggest themselves to those skilled in the art. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. A gaseous discharge device comprising an envelope containing cooperating electrodes and an ionizable atmosphere, one of said electrodes being a cathode and another an anode, said cathode comprising a primary cathode of solid metal, a heater for heating said primary cathode to temperature of thermionic emission, whereby an ionizing discharge may be started between said primary cathode and said anode, and a hollow secondary cathode having an interior electron-emitting surface out of substantial heat transfer relation with respect to said primary cathode heater disposed immediately adjacent the discharge path between said primary cathode and said anode, whereby said secondary cathode interior surface is heated by the discharge to temperature of thermionic emission, said primary cathode having as an element thereof a shielding member shielding the emitting surface of said primary cathode from the emitting surface of said secondary cathode, whereby heat transfer from said primary cathode surface to said secondary cathode surface is inhibited, said secondary cathode also having a discharge opening whereby the discharge may pass to said anode.

2. A gaseous discharge device comprising an envelope containing cooperating electrodes and an ionizable atmosphere, one of said electrodes being a cathode and another an anode, said cathode comprising a primary cathode of solid metal, a heater for heating said primary cathode to temperature of thermionic emission, whereby an ionizing discharge may be started between said primary cathode and said anode, and a secondary cathode out of substantial heat transfer relationship with respect to said primary cathode and having an extended surface with one part thereof disposed immediately adjacent the primary cathode and the discharge path between said primary cathode and said anode, adjoining areas of said extended surface being spaced progressively greater distances from said primary cathode, whereby said discharge heats successively greater areas of said secondary cathode to temperature of electron emission as the amount of current in the discharge increases.

3. A gaseous discharge device comprising an envelope containing cooperating electrodes and an ionizable atmosphere, one of said electrodes being a cathode and another an anode, said cathode comprising a primary cathode, a heater for heating said primary cathode to temperature of thermionic emission, whereby an ionizing discharge may be started between said primary cathode and said anode, and a secondary cathode out of substantial heat transfer relationship with respect to said primary cathode and disposed adjacent the discharge path between said primary cathode and said anode, whereby at least a portion of said secondary cathode is heated by the discharge to temperature of electron emission, said secondary cathode comprising a solid member having an extended surface, said surface composed of a material having a relatively great thermal conductivity and emitting large numbers of electrons at the temperature to which it is raised by the discharge, whereby as the amount of current in said discharge is increased, adjacent areas of said surface are heated to thermionic emission and the discharge distributes itself over said surface.

4. A space discharge device comprising an envelope containing cooperating electrodes, one of said electrodes being a solid cathode and another an anode, a lead-in conductor for said cathode sealed through a wall of said envelope, and a pool of a metal which is liquid at operating temperatures within said container, said pool communicating with the space in which said electrodes are located for furnishing a vapor to said space, said lead-in conductor being in intimate contact with said pool, said cathode being in intimate contact with said pool at another point, whereby electrical connection between said cathode and lead-in conductor is established through said pool.

5. A space discharge device comprising an envelope containing cooperating electrodes, one of said electrodes being a solid cathode and another an anode, a lead-in conductor for said cathode sealed through a wall of said envelope, and a pool of mercury, said pool communicating with the space in which said electrodes are located for furnishing a vapor to said space, said lead-in conductor being in intimate contact with said pool, said cathode being in intimate contact with said pool at another point, whereby electrical connection between said cathode and lead-in conductor is established through said pool.

6. A space discharge device having an envelope with a glass wall, electrodes within said envelope, a lead-in conductor for one of said electrodes sealed through said glass wall, a clamping member secured to the exterior of said envelope adjacent said lead-in conductor, a flexible conductor having one end secured to said lead-in conductor and the other end to said clamping member, and means for establishing electrical connection to said flexible conductor at a point beyond said clamping member on the other side thereof from said lead-in conductor.

7. A space discharge device having an envelope with a glass wall, an electrode within said envelope, a lead-in conductor for said electrode sealed through said glass wall, a flexible conductor having one end secured to said lead-in conductor and the other end secured to the envelope, and means for establishing electrical con-

nection to said flexible conductor at a point beyond where it is secured to said envelope on the other side thereof from said lead-in conductor, and an additional electrode cooperating with said first electrode.

8. A space discharge device having an envelope comprising a glass body through which a lead-in conductor is adapted to be sealed, an electrode within said envelope, a lead-in conductor for said electrode sealed through said glass body, a flexible conductor having one end secured to said lead-in conductor and a point beyond said end secured to the envelope, and means electrically connected to said flexible conductor at a point beyond where it is secured to said envelope on the other side thereof from said lead-in conductor, and an additional electrode cooperating with said first electrode.

9. A gaseous discharge device comprising an envelope containing an ionizable atmosphere, a cathode, and a plurality of anodes disposed around said cathode, each of said anodes being surrounded with a shield, each shield having a discharge opening whereby a discharge may pass from said cathode to the anode, the discharge openings in said shields each facing a solid wall of the adjacent anode shield.

10. A gaseous discharge device comprising an envelope containing an ionizable atmosphere, a cathode, and a plurality of anodes disposed around said cathode with their central points in substantially a common plane, each of said anodes comprising a flat conducting plate disposed at an angle to said common plane and at an angle with respect to any plane at right angles to said common plane.

11. A gaseous discharge device comprising an envelope containing cooperating electrodes and an ionizable atmosphere, a cathode, and a plurality of anodes disposed around said cathode with their central points in substantially a common horizontal plane, each of said anodes comprising a flat conducting plate disposed at an angle to said common plane and at an angle with respect to any plane at right angles to said common plane, each of said anodes being surrounded with a shield, each shield having a discharge opening whereby a discharge may pass from said cathode to the anode, the discharge openings in said shields facing downwardly and a solid wall of each anode shield facing upwardly.

12. A gaseous discharge device comprising an envelope containing cooperating electrodes and an ionizable atmosphere, one of said electrodes being a cathode and another an anode, a shield surrounding said anode, a lead-in conductor sealed through a wall of said envelope, and a perforated shield surrounding said lead-in conductor within said envelope and connected to said first-named shield.

13. A gaseous discharge device comprising an envelope containing cooperating electrodes and an ionizable atmosphere, one of said electrodes being a cathode and another an anode, a shield surrounding said anode, a lead-in conductor sealed through a wall of said envelope, and a perforated shield surrounding said lead-in conductor within said envelope.

14. A gaseous discharge device comprising an envelope containing cooperating electrodes and an ionizable atmosphere, one of said electrodes being a cathode and another an anode, a shield surrounding said anode, a reentrant stem in said envelope, a lead-in conductor sealed through said stem, a perforated shield surrounding said lead-in conductor within said envelope and connected to said first-named shield, said perforated shield being fastened onto said stem, and a rigid stay fastened at one end to said stem and at the other end to said first-named shield, whereby both of said shields are firmly supported by said stem.

15. A gaseous discharge device comprising an envelope containing cooperating electrodes and an ionizable atmosphere, one of said electrodes being a cathode and another an anode, a shield surrounding said anode, a reentrant stem in said envelope, a lead-in conductor sealed through said stem, a perforated shield surrounding said lead-in conductor within said envelope and connected to said first-named shield, said perforated shield being fastened onto said stem, a rigid stay fastened at one end to said stem and at the other end to said first-named shield, whereby both of said shields are firmly supported by said stem, and reinforcing strips on one side of said perforated shield for assisting in said support.

16. A gaseous discharge device comprising an envelope containing cooperating electrodes and an ionizable atmosphere, one of said electrodes being a cathode and another an anode, a shield surrounding said anode, a lead-in conductor sealed through a wall of said envelope, a perforated shield surrounding said lead-in conductor within said envelope and connected to said first-named shield, and two shielding members connected respectively to said perforated shield and lead-in conductor and spaced apart a sufficiently short distance to prevent a discharge from passing to said anode through said perforated shield.

17. A gaseous discharge device comprising an envelope containing cooperating electrodes and an ionizable atmosphere, one of said electrodes being a cathode and another an anode, a shield surrounding said anode, a lead-in conductor sealed through a wall of said envelope, a perforated shield surrounding said lead-in conductor within said envelope and connected to said first-named shield, and two shielding members connected respectively to said perforated shield and lead-in conductor and spaced a short distance apart.

18. A space discharge device comprising a sealed envelope containing an anode and a cathode having a discharge surface, said cathode discharge surface being composed of a bare solid metal, a mixture of a vaporizable material for furnishing an ionizable vapor for supporting a discharge between said cathode and anode and a material which enhances and maintains the electron-emitting qualities of said discharge surface when conveyed thereto, and means for continuously conveying said mixture to said discharge surface, during operation.

19. In a gaseous discharge device comprising a sealed envelope containing an anode and a cathode having a discharge surface, said discharge surface being composed of a bare solid metal, the method of constantly renewing the electron-emitting properties of said cathode which comprises continuously conveying to said discharge surface the vapor of an easily vaporizable material, said vapor constituting an ionizable atmosphere within said envelope and causing said vapor so conveyed to said discharge surface to carry along with it an activating material which enhances and maintains the electron-emitting qualities of said discharge surface.

20. A space discharge device comprising a sealed envelope containing an anode and a cath-

ode having a discharge surface, said discharge surface being composed of a bare solid metal, a mixture of a vaporizable material for furnishing an ionizable vapor for supporting a discharge between said cathode and anode and an alkaline metal which enhances and maintains the electron-emitting qualities of said discharge surface when conveyed thereto, and means for continuously conveying said mixture to said discharge surface during operation.

21. In a gaseous discharge device comprising a sealed envelope containing an anode and a cathode having a discharge surface, said discharge surface being composed of a bare solid metal, the method of constantly renewing the electron-emitting properties of said discharge surface which comprises conveying to said discharge surface the vapor of an easily-vaporizable material, said vapor constituting an ionizable atmosphere within said envelope and causing said vapor so conveyed to said discharge surface to carry along with it an alkaline metal which enhances and maintains the electron-emitting qualities of said discharge surface.

22. A gaseous discharge device comprising an envelope containing cooperating electrodes and an ionizable atmosphere, one of said electrodes being a cathode and another an anode, said cathode comprising a primary cathode of solid metal having a surface adapted to be heated to thermionic emission, a heater for heating said primary cathode surface to temperature of thermionic emission, whereby an ionizing discharge may be started between said primary cathode and said anode, and a secondary cathode of solid metal out of substantial heat transfer relation with respect to said primary cathode heater and having a surface disposed immediately adjacent the discharge path between said primary cathode and said anode, whereby said secondary cathode is heated by the discharge, said surface being coated with a thermionically-active material during operation and being adapted to emit large numbers of electrons thermionically at the temperature to which it is raised by said discharge.

23. A gaseous discharge device comprising an envelope containing an ionizable atmosphere, a cathode, and a plurality of anodes, each of said anodes being surrounded with a shield, each shield having a discharge opening whereby a discharge may pass from said cathode to the anode, the walls of said shield interrupting all straight-line discharge paths between adjacent anodes by having the discharge openings in said shields each facing a wall of the adjacent anode shield.

24. A space discharge device comprising a sealed envelope containing an anode and a cathode having a discharge surface, said cathode discharge surface being composed of a bare solid metal, a mixture of a vaporizable material for furnishing an ionizable vapor for supporting a discharge between said cathode and anode and a material which enhances and maintains the electron-emitting qualities of said discharge surface when conveyed thereto, and means for conveying said mixture to said discharge surface during operation.

25. In a gaseous discharge device comprising a sealed envelope containing an anode and a cathode having a discharge surface, said discharge surface being composed of a bare solid metal, the method of renewing the electron-emitting properties of said cathode which comprises conveying to said discharge surface the vapor of an easily vaporizable material, said vapor constituting an ionizable atmosphere within said envelope and causing said vapor so conveyed to said discharge surface to carry along with it an activating material which enhances and maintains the electron-emitting qualities of said discharge surface.

26. A space discharge device comprising a sealed envelope containing an anode and a cathode having a discharge surface, said discharge surface being composed of a bare solid metal, a mixture of a vaporizable material for furnishing an ionizable vapor for supporting a discharge between said cathode and anode and an alkaline metal which enhances and maintains the electron-emitting qualities of said discharge surface when conveyed thereto, and means for conveying said mixture to said discharge surface during operation.

27. In a gaseous discharge device comprising a sealed envelope containing an anode and a cathode having a discharge surface, said discharge surface being composed of a bare solid metal, the method of renewing the electron-emitting properties of said discharge surface which comprises conveying to said discharge surface the vapor of an easily-vaporizable material, said vapor constituting an ionizable atmosphere within said envelope and causing said vapor so conveyed to said discharge surface to carry along with it an alkaline metal which enhances and maintains the electron-emitting qualities of said discharge surface.

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