

Oct. 5, 1937.

P. L. SPENCER

2,094,760

HIGH POWER RECTIFIER

Filed March 6, 1936

4 Sheets-Sheet 1

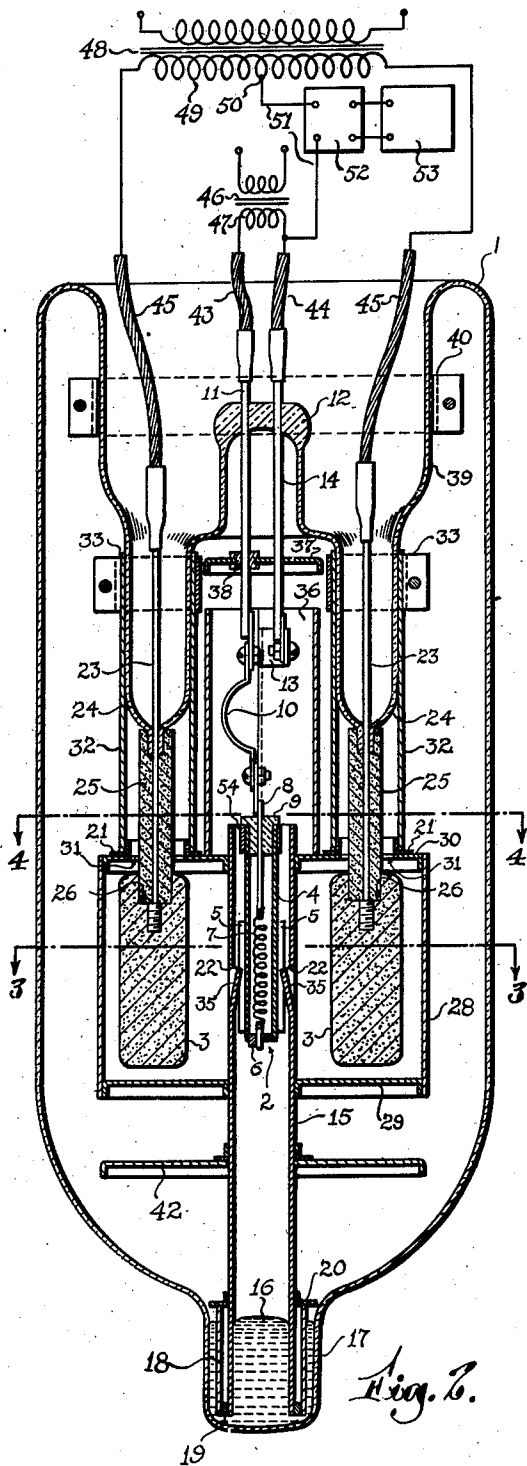


Fig. 1.

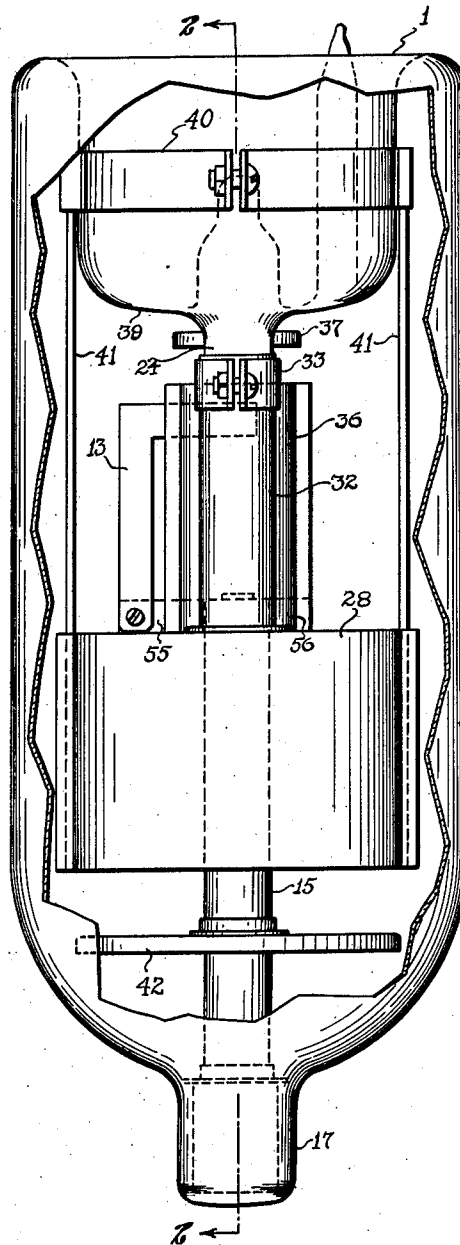


Fig. 2.

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Fig. 3.

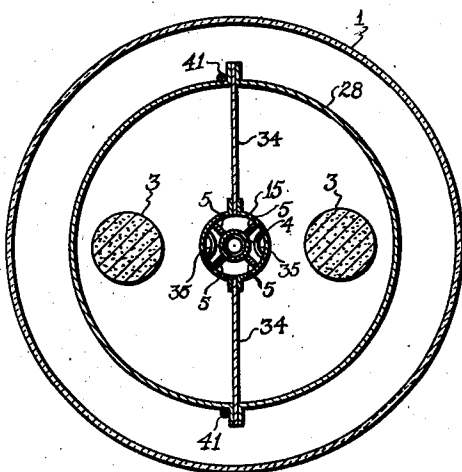


Fig. 4.

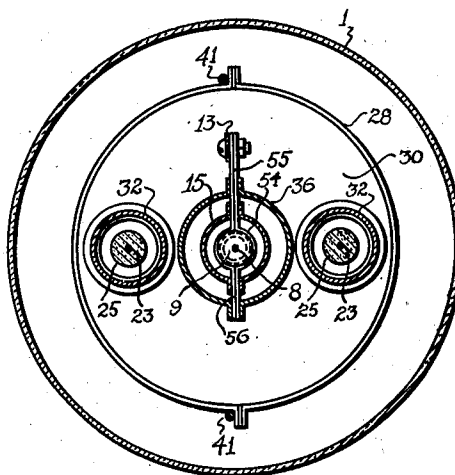


Fig. 5.

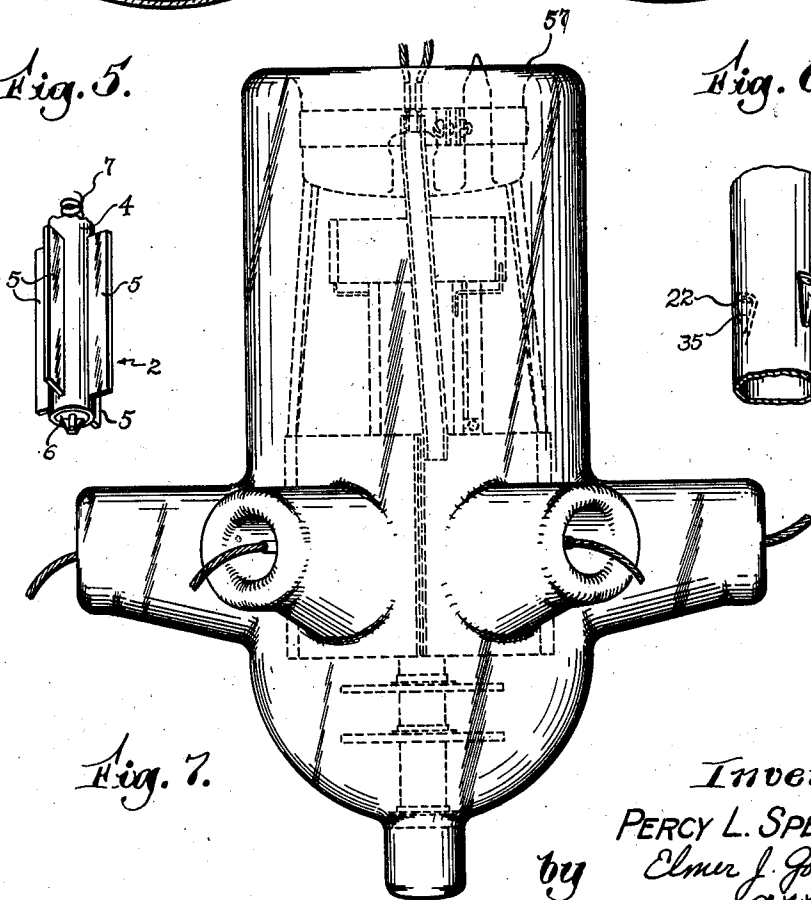


Fig. 6.

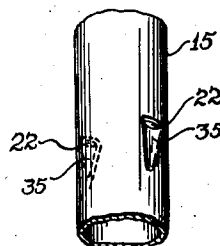


Fig. 7.

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Fig. 8.

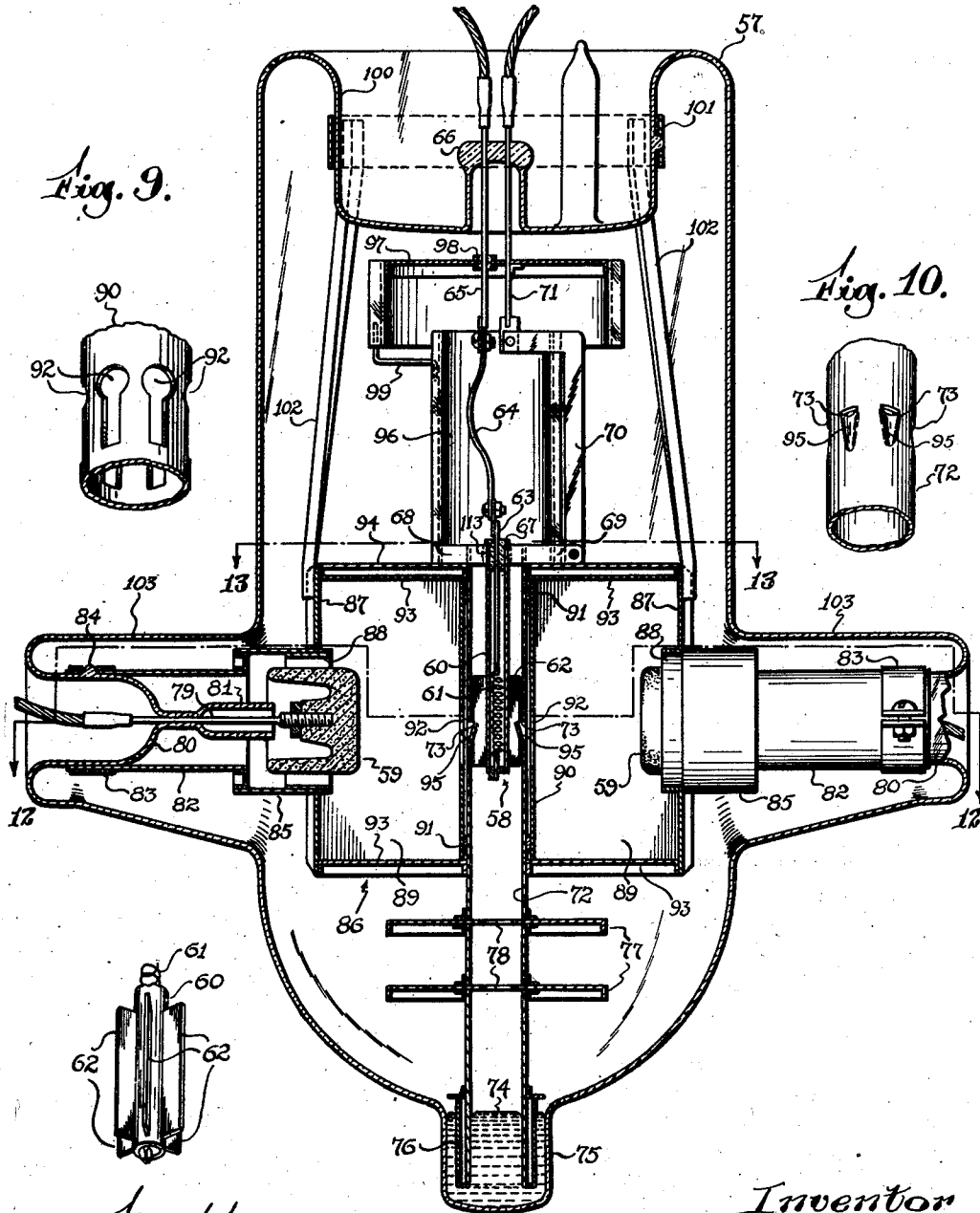


Fig. 9.

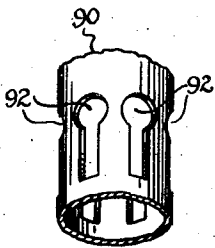


Fig. 10.

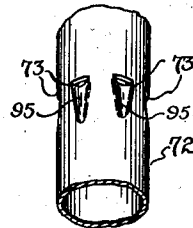
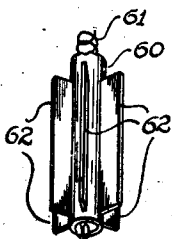


Fig. 11.

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4 Sheets-Sheet 4

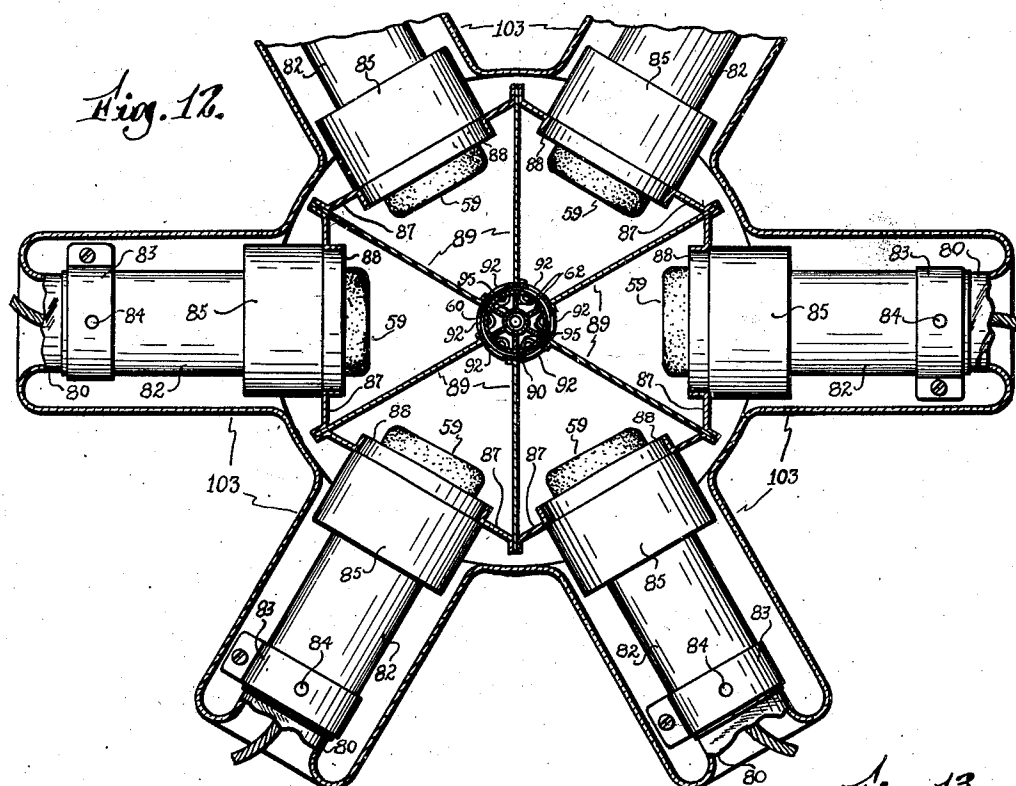


Fig. 13.

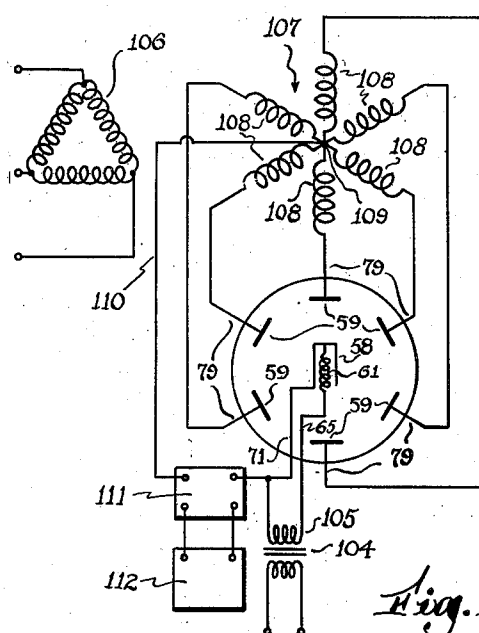
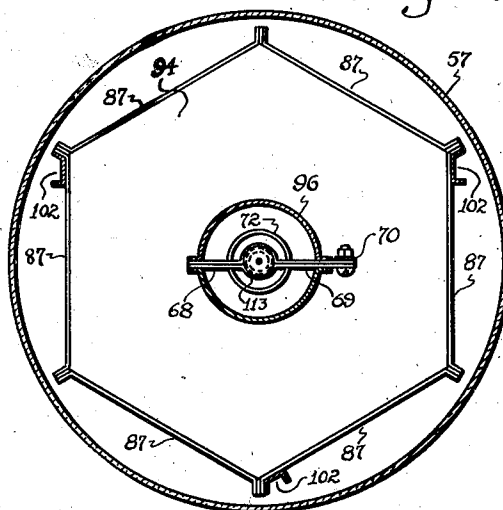


Fig. 14.

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UNITED STATES PATENT OFFICE

2,094,760

HIGH-POWER RECTIFIER

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Application March 6, 1936, Serial No. 67,477

16 Claims. (Cl. 250—27.5)

This invention relates to high-power rectifiers, and more particularly to such rectifiers in which the current is carried by an ionized gaseous discharge.

5 An object of this invention is to devise such a rectifier which is capable of carrying large amounts of current and withstanding high reverse voltages with a minimum of flashback.

10 Another object of this invention is to so construct the rectifier that the possibility of material particles getting onto the anodes is substantially eliminated.

15 A further object of this invention is to reduce the inverse current drawn by the anodes to a minimum.

A still further object is to devise an arrangement whereby the control of pressure around the anode may be effected substantially independent of ambient temperature around the device.

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

25 Fig. 1 is a side view of one embodiment of my invention, with the front glass wall partly broken away;

30 Fig. 2 is a vertical section taken along the line 2—2 of Fig. 1 and in addition has a diagrammatic showing of one circuit with which the tube may be used;

Fig. 3 is a cross-section taken along line 3—3 of Fig. 2;

35 Fig. 4 is a cross-section taken along line 4—4 of Fig. 2;

Fig. 5 is a perspective view of a portion of the cathode of the tube shown in Figs. 1 and 2;

40 Fig. 6 is a perspective view of a portion of the conduit surrounding the cathode of Figs. 1 and 2;

Fig. 7 is a side view of another embodiment of my invention showing a six-anode rectifier;

Fig. 8 is a vertical section of the tube shown in Fig. 7;

45 Figs. 9 and 10 are perspective views of portions of the conduit and cylinder surrounding the cathode of Fig. 8;

Fig. 11 is a perspective view of a portion of the cathode of Fig. 8;

50 Fig. 12 is a cross-section taken along line 12—12 of Fig. 8;

Fig. 13 is a cross-section taken along line 13—13 of Fig. 8; and

55 Fig. 14 is a diagrammatic view of a circuit in which the tube of Fig. 8 may be used.

In rectifiers, and particularly those which are intended to carry high currents and withstand high reverse voltages, difficulties have heretofore been encountered in that such devices had a tendency to flash back, that is, that current 5 would flow through the device in the reverse direction substantially at the same voltage as it would flow in the conducting direction, and therefore the device no longer acted as a rectifier. Flashbacks are particularly destructive, 10 not only to the tube itself but also to the apparatus with which the tube is connected. The art has attempted to take care of flashbacks primarily by the use of auxiliary protective devices associated with the rectifier. However, these 15 devices are expensive and relatively unsatisfactory. The present invention is one which substantially eliminates the probability of flashback.

Flashback is a haphazard occurrence which 20 nevertheless is dependent upon a certain number of independent factors. One factor which affects the occurrence of flashbacks is the deposition of material particles on the anode. Such particles may consist of material liberated from 25 the cathode itself or from various other parts within the tube. In the case where vapor, such as mercury vapor, is used as the ionized medium, the particles may include small droplets of mercury. Such particles can get onto the anodes in 30 various ways. For example, previous devices were so constructed that vapor or gas streams occurred which were often directed toward the anode, and in this way the stream which carried the particles would transfer these particles 35 onto the anode. Even where definite streams of gas or vapor were absent, particles within the interior of the tube would be conveyed, by the action of the "Brownian" movement of the gaseous atoms in the tube, to the anode. 40

Another factor which affects flashbacks is the magnitude of the inverse current carried by the anode. An increase in inverse current increases the frequency at which flashbacks occur while a decrease in the magnitude of the inverse current decreases the frequency at which flashbacks occur. Where but a single anode is present, the ordinary inverse current is due to the anode attracting, during the inactive part of the cycle, residual positive ions which are created 45 during the active part of the cycle but which persist for a certain length of time after the anode has become negative. Of course if the surface of the anode has become contaminated by a particle being deposited upon it and the anode is 55

sufficiently hot to emit electrons at that point, the apparent inverse current will be increased due to the fact that the anode is acting partly as a cathode during the inactive part of the cycle. The present invention decreases the inverse current not only by substantially eliminating the possibility of any particles getting onto the anode, but also by decreasing the vapor density adjacent the anode. The number of positive ions which exist adjacent the anode is dependent to a large degree upon the vapor density, and therefore a decrease in the vapor density adjacent the anode will decrease the amount of inverse current due to residual ionization.

While the problem of flashbacks has existed to a considerable degree even with a single anode, it has been most marked in the case where a plurality of anodes were attempted to be used in a single rectifier. Rectifier tubes having two or more anodes so as to rectify both halves of alternating voltages applied to such a tube had the frequency of flashback occurrence greatly increased over the case of a single anode rectifier. One factor affecting flashbacks which is greatly increased in the ordinary multiple anode tube is the inverse current which each anode carries. This increase is due to the fact that while one of the anodes is idle, some other anode in the tube is conducting current and producing ionization within the tube. The ions created by such an active anode are accessible to the other anodes in the tube, and thus the idle anode being at a negative potential attracts some of these ions and greatly increases the amount of inverse current which that idle anode draws. Other factors which increase the tendency for multiple anode tubes to flashback are those introduced by the increased tendency for material particles to be deposited onto the anodes. The presence of a plurality of anodes energized in various phase relationships to each other produces rotating or moving magnetic and electrostatic fields which tend to produce vapor or gas swirls within the tube and which in turn increase the tendency of any particles within the tube to reach the anodes.

The present invention decreases all of the above-noted effects tending to reduce flashbacks to a minimum so that two and six anode tubes of high voltage and current capacity have been constructed and operated for periods of many hundreds of hours without any flashbacks occurring.

In Figs. 1 to 6, inclusive, there is illustrated one form of a plural anode rectifier incorporating the above principles. The rectifier comprises a glass envelope 1 containing a cathode 2, and a plurality of anodes 3. The cathode, as shown most clearly in Figs. 2 and 5, consists of a cylinder 4 of a refractory metal, such as, for example, tantalum carrying a plurality of external radial fins 5, preferably of the same metal as that of the cylinder 4. The lower end of the cylinder 4 is closed by a metal plug 6. The exterior of the cylinder 4 and the fins 5 may be coated with an electron-emissive coating, such as, for example, the oxides of the alkaline earth metals, although it is possible and often desirable merely to oxidize these surfaces which become activated by subsequently depositing an activating material thereon, as will be described below. The exterior of the cylinder 4 and the fins 5 are heated to a temperature of thermionic emission by means of a heating filament 7 placed within the cylinder 4 and connected at its lower end to the plug 6.

The other end of the heating filament 7 is provided with a conductor 8 which passes through an insulating plug 9 closing the upper end of the cylinder 4. The conductor 8 is connected by a flexible lead 10 to a lead-in wire 11 sealed through a glass stem 12, as shown in Fig. 2. In order to provide a connection to the cathode for carrying the load current and also for providing the other terminal for the heating filament, the upper end of the cylinder 4 is surrounded by a clamp 54 which is provided with extensions 55 and 56 at the opposite sides thereof, as shown in Figs. 1 and 4. The outer end of extension 55 has connected thereto a lead 13, the upper end of which is in turn connected to the lead-in wire 14 likewise sealed through the glass stem 12.

As pointed out in the co-pending applications of Marshall and Spencer, Serial No. 605,249, filed April 14, 1932, and Serial No. 729,101, filed June 5, 1934, it is desirable to have a relatively high density of gas or vapor adjacent the emitting surfaces of the cathode and also to provide means for continuously depositing on the emitting surfaces of the cathode a material which maintains the electron-emissive properties thereof. These features are claimed in said co-pending applications. I make use of these principles by surrounding the cathode 2 with a tubular conduit 15, the lower end of which dips into a pool 16 which preferably consists of an easily vaporizable material, such as mercury, with which is mixed an activating material, such as an alkaline earth metal, preferably barium. The glass envelope 1 is provided with a lower well 17 which contains the pool 16 and also the lower end of the conduit 15. The lower end of the conduit 15 is heat insulated, so as to maintain the portion of the pool 16 within the conduit at a higher temperature than the portion thereof external to the conduit. This is accomplished by surrounding the lower end of the conduit 15 by a cylinder 18 spaced a short distance from the exterior walls of the conduit 15. The space between the cylinder 18 and the conduit 15 is closed at the lower end by a ring 19, and at the upper end by an annular cap 20. The heat liberated at the cathode by the heating filament 7 and also by the passage of the discharge will be radiated down onto the upper surface of the pool 16 within the conduit 15, and some heat will also travel down the walls of the conduit 15 to the pool 16. In this way vapor will be liberated in the desired amount from the surface of the pool 16 within the conduit 15, and the vapor stream will pass up the conduit 15 and past the emitting surfaces of the cathode. This action maintains the emitting surfaces of the cathode as described and claimed in said co-pending applications.

The anodes 3 cooperating with the cathode 2 are located outside of the conduit 15, and the discharge from the cathode to each anode passes through an opening 22 provided in the walls of the conduit 15 adjacent each anode. Each anode is mounted on a lead-in conductor 23 which is sealed through a stem 24. The portion of the lead-in conductor 23 between the stem 24 and the anode is protected by a carbon sleeve 25 closely surrounding the lead-in conductor 23. The lower end of the carbon sleeve 25 is preferably seated in a recess 26 provided in the upper end of each anode 3.

In order to decrease the inverse current to each anode to a minimum, each anode is entirely separated from each of the other anodes in the tube, so that the positive ions created by the discharge

passing to one of the anodes are not available to increase the inverse current to any of the idle anodes. Thus the anodes are surrounded by a box-like structure. This box-like structure includes the cylinder 28 surrounding the anodes, and preferably is constructed of two semi-circular plates. The space between the cylinder 28 and the conduit 15 is closed at its lower end by an annular plate 29. The upper end of this space is likewise closed by an annular plate 30 which is provided with a plurality of openings 31 to allow the lead-in wires 23 carrying the carbon sleeves 25 to pass through. These openings 31 are in turn closed off from the interior of the tube by sleeves 32, each fastened at its lower end to the plate 30 by means of a welding ring 21, and clamped at its upper end around the stem 24 by means of a clamp 33. The anodes 3 are separated from each other within the box-like structure by means of partition plates 34 which extend from the top to the bottom of the cylinder 28, completely separating the two anodes. The partition plates 34 are preferably retained in place by being welded at one end thereof between the ends of the semi-circular plates, constituting the cylinder 28, and at the other end thereof between two semi-circular portions constituting the portion of the conduit 15 adjacent thereto.

Although the anodes 3 are separated from each other within the cylinder 28 by means of the partitioning plates 34, yet a path for the passage of positive ions from one anode to another might exist through the openings 22 in the conduit 15. In order to avoid this possibility, the radial fins 5 of the cathode 2, in addition to serving as additional electron-emitting surfaces of the cathode, are so arranged as to intercept any such path between the anodes. For this reason the radial fins 5 are arranged as shown most clearly in Fig. 3, wherein a fin 5 extends on each side of an opening 22 from the cylinder 4 to the inner walls of the conduit 15. In addition, the cathode is operated at a sufficient degree of electron emission so that the cathode surfaces in the region adjacent each opening 22 and surrounded by the two adjacent fins 5 emit a sufficient number of electrons to carry the maximum current flowing to the anode adjacent said opening. In this way the ionization adjacent the cathode, due to said anode, will be confined to the space bounded by said two fins 5, and will not be available for passage through the opening 22 adjacent the idle anode so as to increase the inverse current which can be drawn by that idle anode. The complete enclosure of each anode in the manner indicated also decreases the amount of inverse current due to residual ionization adjacent each anode. The structure surrounding each anode provides a large amount of recombining surfaces for the residual ions so that at the termination of the active part of the cycle, the residual ions will tend to recombine largely on these recombination surfaces, and relatively few of these residual ions will be available to supply inverse current to the anode.

The jet of vapor from the pool 16, which as previously mentioned passes up past the surfaces of the cathode, continues from the cathode up through the open upper end of the conduit 15. In this way the possibility of the vapor stream being directed toward the anodes is substantially eliminated, so that particles carried by the stream instead of being carried toward the anodes are carried away from the anodes. The action of the jet instead of producing a detrimental effect in

the tube is made to produce a beneficial effect by the indentation of the walls of the conduit 15 below each opening 22 forming a louvre 35. In this way an aspirator action is produced at each opening 22, tending to evacuate the space adjacent each of the anodes 3. This aspirator tends to remove any particles which may exist in the space adjacent the anodes, and therefore the movement of any such particles, instead of being in a direction toward the anodes, is in a direction away from the anodes so that the possibility of such particles getting onto the anodes is greatly decreased. Furthermore, the anodes being completely enclosed, as shown, the aspirator action will produce a decrease in the gas or vapor density adjacent the anodes, and as pointed out above this in turn will produce a decrease in the amount of residual ionization adjacent each anode, which in turn will reduce the amount of inverse current drawn by the anodes. The evacuation by the vapor stream of the anode region can be so designed that the pressure conditions around the anodes are made substantially independent of the ambient temperature surrounding the envelope 1. Also this action produces a steady pressure condition adjacent each anode, which pressure condition is not subjected to any sudden variations or disturbances which might exist if the complete separation shown was not present. This steady pressure or density state of the vapor or gas adjacent the anodes eliminates the possibility of any sudden swirls or eddies of vapor which would upset pressure conditions adjacent the anode, and might carry particles onto the anode. If such conditions are present, it has been found that the anodes tend to flash back. Having eliminated these conditions in the arrangement shown, this factor tending to produce flashbacks is eliminated.

In order further to isolate the anodes and make the pressure conditions adjacent to them substantially independent of anything which occurs in the rest of the tube, an upper duct 36 is provided which surrounds the upper end of the conduit 15 and extends from the plate 30 to a level considerably above the upper end of the conduit 15. The duct 36 is also preferably made of two semi-circular plates, and is held in place by having these plates welded at their lower ends on opposite sides of the extensions 55 and 56, and at their upper ends on opposite sides of the conductor 13. The upper end of the duct 36 is open so that the vapor which passes up through the conduit 15 and into the duct 36 is free to pass out into the space within the glass envelope 1. The vapor thus passing out into the envelope 1 condenses and runs back into the pool 16. The duct 36 prevents drops of vapor, which condense within the envelope 1 and drop down onto various parts of the structure therein, from splashing back into the conduit 15. Therefore, the possibility of any condensed vapor drops passing into the discharge space where they might create pressure disturbances which tend to produce a flashback is substantially eliminated. In order further to eliminate the possibilities of any such droplets falling directly into the duct 36, a shield cap 37 is provided over the upper end of the duct 36 so as to prevent any droplets from falling directly into the duct 36. The cap 37 may be supported by being welded to one of the lead-in conductors 14. It is insulated from the other lead-in conductor 11 by an insulator 38.

The stems 12 and 24 are formed as part of a larger reentrant stem 39 in the upper end of the

glass envelope 1. In order to remove strain from the stems 12 and 24 and in order to support the structure within the tube more rigidly, a clamp 40 is provided around the stem 39. This clamp 40 carries a plurality of supporting rods 41, each welded at its upper end to the clamp 40 and at its lower end to the cylinder 28. In this way most of the weight of the structure within the envelope is supported from the clamp 40 and is removed from the stems 12 and 24. In order to prevent an excess amount of heat from being radiated to the lower wall of the envelope 1, which in turn would tend to evaporate mercury from the external portion of the pool 16, an annular shield 42 is provided below the plate 29, and is supported by being welded to the outer wall of the conduit 15.

The lead-in wires 11, 14 and 23 are preferably provided with external flexible leads 43, 44 and 45, respectively. In order to supply heating current for the heating filament 7, a transformer 46 having its secondary 47 connected to the two leads 43 and 44 is provided. In order to supply the main current to be rectified, a load transformer 48 may be provided whose secondary 49 has its opposite ends connected to the two leads 45 which in turn are connected to the two anodes 3. Since the flexible lead 44 which is connected to the lead-in wire 14 is connected directly to the cathode, it is made to serve as one of the leads for the load current. A center tap 50 is provided on the secondary 49 which has a connection 51 extending to the lead 44. In the connection 51 may be connected a filter 52 to the output terminals of which a load 53 may be connected.

When the transformers 46 and 48 are energized, the heating filament 7 will raise the cathode to temperature of thermionic emission, a stream of vapor will be given off from the pool 16, and a discharge will flow between the cathode 2 and the anodes 3, resulting in the flow of a rectified current through the connection 51. This current will be smoothed out by the filter 52, and a substantially uniform direct current will flow through the load 53. As described above, the tube under such operation will be able to handle large currents and voltages without danger of flashback.

If it is desired to increase the size of the anodes, the spacing between them, and the number of anodes involved over that shown in Figs. 1 to 6, inclusive, a structure such as that illustrated in Figs. 7 to 14, inclusive, may be utilized. In these figures the tube shown comprises a glass envelope 57 containing a cathode 58 and a plurality of anodes 59. In the embodiment shown in these figures, six such anodes are shown. The cathode is very similar to that described above, and consists of a cylinder 60 having a heating filament 61 within it and carrying a plurality of radial fins 62. With the six anodes, the cathode carries six such radial fins. This cathode may be either coated or uncoated, and activated in the same manner as the cathode described above. The heating filament is provided with a conductor 63 connected by a flexible lead 64 to the lead-in conductor 65 sealed through the stem 66. An insulator 67 insulates the conductor 63 from the cylinder 60. The cathode connection and also the return connection for the heating filament 61 is provided by a clamp 68 surrounding the upper end of the cylinder 60 and provided with extensions 68 and 69. To the outer end of the extension 69 is connected a flexible lead 70 which in turn is connected at its upper end to the lead-in conductor 71 also sealed through the stem 66.

As in the case of Fig. 2, the cathode 58 is surrounded with conduit 72 having a plurality of openings 73 through which the discharge passes from the cathode 58 to the respective anodes 59. The lower end of the conduit 72 dips down into a pool 74 contained in the lower well 75 of the envelope 57. The pool 74 likewise preferably consists of a mixture of barium and mercury. The end of the conduit 72 dipping into the pool 74 is insulated by a heat shield 76 of similar construction to that shown in Fig. 2. In order to control and regulate the amount of vapor given off from the pool 74, one or more heat baffles 77 are interposed between the cathode structure and the pool 74. These heat baffles extend into the conduit 72, and are provided with central openings 78 through which the vapor given off from the pool 74 may pass, and likewise through which heat from the cathode structure may be radiated down onto the pool in order to produce the vaporization. By regulating the size of the opening 78, the amount of vapor given off from the pool 74 may likewise be regulated. By making the heat baffles continuous from the openings 78 to the exterior of the conduit 72, the radiant heat intercepted by the heat baffles 77 is radially conducted along these heat baffles and radiated by the portion thereof external to the conduit 72. Likewise by intercepting the continuity of the walls of the conduit 72 by the interposition of the heat baffles 77, the amount of heat conducted directly down along the walls of the conduit is reduced to a relatively small amount, and therefore the amount of vapor produced is determined primarily by the size of the openings 78.

Each anode 59 is mounted upon a lead-in conductor 79 sealed through a stem 80. In order to produce a high-leakage path along the seal of the stem 80 in the case where high voltages are being used, the stem 80 may be provided with an integral sleeve 81 surrounding the lead-in conductor 79 and extending from the stem 80 to the end of the anode 59. Each anode is likewise provided with a shield 82, the outer end of which is clamped around the stem 80 by means of a clamp 83, and is prevented from rotating on the stem 80 by means of a glass bead 84 projecting into a cooperating opening in the shield 82 and the clamp 83. The shield 82, which at one end is of the same diameter as the stem 80, may be provided with a portion 85 of increased diameter at the other end so as to be sufficiently spaced from the sides of the anode 59, as indicated most clearly in Fig. 8.

In order to provide for the complete separation of the anodes from each other, a box-like structure 86 between the cathode 58 and the anodes 59 is provided. This box-like structure contains six side wall plates 87 each adjacent its respective anode. Each side wall plate is provided with a central opening through which the end of the anode can project. In this opening is welded a sleeve 88 over the outer end of which the member 85 fits snugly. Between each one of the side wall plates 87 is welded a partition wall 89 which extends from the side wall plates to a cylindrical member 90 surrounding the conduit 72 within the box-like structure 86. This cylindrical member 90 is provided so that the partition walls 89 may be readily welded thereto. The cylindrical member 90 is preferably placed as close as possible to the outer walls of the conduit 72, but may be spaced therefrom at a definite distance by means of spacing

members 91. In order to provide a passage for each of the anode discharges, the cylindrical member 90 is provided with openings 92 each adjacent the corresponding opening 73 in the conduit 72. The top and the bottom of the box-like structure 86 are closed by means of a plurality of wedge-shaped plate sectors 93. In order to prevent the accumulation of any condensed mercury on the top of the box-like structure, it is further provided with a smooth plate 94 covering the top wedge-shaped sector plates 93. The plate 94 is provided with a central opening through which the upper end of the conduit 72 projects.

In order to complete the separation between the anodes, the radial fins 62 of the cathode 58 extend from the outer walls of the cylinder 60 to the inner walls of the conduit 72. Each radial fin is located intermediate two openings 73 so that each pair of radial fins completely separates each opening 73 from each of the other openings 73. By operating the cathode at a sufficient degree of emissivity so that the section of the cathode adjacent each opening 73 supplies sufficient emission to carry the maximum current to its respective anode, the discharge to the anode is confined to that portion of the cathode, and therefore the ionization due to said anode is confined adjacent the cathode to the region bounded by two adjacent radial fins 62. As in the case of the previous modification, this arrangement prevents ionization from any active anode from reaching an idle anode so as to increase the inverse current thereto. By operating the cathode at the degree of emissivity suggested, the ionization does not extend below the lower end of the cathode 58 nor above the upper end thereof, and in this way substantially no ions can travel from one anode discharge to another.

As in the case of the first embodiment described, the conduit 72 is provided below each of the openings 73 with an indentation forming a louvre member 95. These louvre members produce the aspirating action which results in the various advantages as pointed out in connection with said first modification. The structure is also provided with an upper duct member 96 consisting of two semi-cylindrical plates welded together on opposite sides of the projections 68 and 69 and on the opposite sides of the upper end of the flexible conductor 70. The upper end of the duct 96 is protected against condensed vapor droplets falling into it by the shielding cap 97 which may be supported by being welded together to the lead-in conductor 71. The cap may be insulated from the lead-in conductor 65 by means of an insulator 98. The shielding cap 97 may further be steadied by means of a stay wire 99 welded to the cap 97 and the duct 96.

The stem 66 is formed as part of a reentrant portion 100 in the upper end of the envelope 57. The reentrant portion 100 is provided with a clamp 101 which in turn carries a plurality of supporting channels 102 welded at their upper ends thereto and at their lower ends to the box-like structure 86, whereby the weight of the internal structure of the tube is supported mainly from the reentrant portion 100. Each of the anode stems 80 is formed in the outer end of radial arms 103 of the side walls of the envelope 57. In assembling the tube shown, the internal structure, with the exception of the anodes and anode shields, is sealed within the envelope 57. Each anode stem 80 carrying its anode 59 and

associated shield 82 is inserted through the outer end of an arm 103 until the member 85 slides over the outer end of sleeve 88. The stem 80 is then sealed in the outer end of the arm 103.

The six-anode structure described above may be connected in any suitable circuit, one of which is shown for example in Fig. 14. A heating transformer 104 has its secondary 105 connected to the two conductors 71 and 65 so as to supply heating current to the heating filament 61. In order to supply the main load current to be rectified, a load transformer having a three-phase primary winding 106 and a six-phase secondary winding 107 is provided. The outer end of each of the secondary coils 108 of the secondary winding 107 is connected to one of the conductors 79, and thus to an anode 59. The central point 109 of the secondary winding 107 is provided with a connection 110 extending to the cathode conductor 71. The connection may be provided with a filter 111, to the output terminals of which is connected a load 112.

When the load and heating transformer are energized, heating current flowing in the heating filament 61 raises the cathode to temperature of thermionic emission, and produces a flow of vapor from the pool 74 up through the conduit 72, supplying an ionizable vapor within the tube and also performing the various other functions described above. The potential impressed between the cathode 58 and the anodes 59 by means of the secondary coils 108 initiates an ionizing discharge between the cathode 58 and each of the anodes 59 through the respective openings 73 and 92. This causes a rectified current to flow through the connection 110, which current is in turn smoothed by the filter 111 so that a steady direct current flows in the load 112.

This invention is not limited to particular details of construction, materials, or processes as described above as many equivalents will suggest themselves to those skilled in the art. For example, certain features of this invention, particularly those associated with the complete separation of the anodes from each other, may be utilized without incorporating the jet action of the vapor stream. Furthermore, any suitable type of cathode may be used which does not necessarily depend upon reactivation by depositing active material thereon for its continued life. Other modifications and equivalents will readily present themselves. 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. An electrical space discharge device comprising an envelope containing a cathode and an anode spaced apart to provide a discharge path between them, a body of vaporizable material adapted to supply a vapor filling to said envelope, surfaces within said envelope upon which said vapor condenses, means for conducting said vapor through said discharge path in a direction away from said anode to said condensing surfaces, and means separating and shielding said discharge path from all of said surfaces upon which said vapor may condense, whereby condensed particles are prevented from entering said discharge path from said surfaces.

2. An electrical space discharge device comprising an envelope containing a cathode and an anode spaced apart to provide a discharge path between them, an enclosure enclosing said anode, the wall of said enclosure being perforated to

provide an opening in said enclosure wall, a gas filling in said envelope, means for producing a stream of said gas filling past said opening, and means adjacent said opening to produce an aspirator action by said stream tending to evacuate said enclosure.

3. An electrical space discharge device comprising an envelope containing a cathode and an anode spaced apart to provide a discharge path between them, a body of vaporizable material adapted to supply a vapor filling to said envelope, surfaces within said envelope upon which said vapor condenses, an enclosure enclosing said anode, the wall of said enclosure being perforated to provide an opening in said enclosure wall, means for producing a stream of said vapor filling past said opening to said condensing surfaces, means adjacent said opening to produce an aspirator action by said stream tending to evacuate said enclosure, and means separating and shielding said discharge path from all of said surfaces upon which said vapor may condense, whereby condensed particles are prevented from entering said discharge path from said surfaces.

4. An electrical space discharge device comprising an envelope containing a cathode and a plurality of anodes, each anode spaced from said cathode to provide a separate discharge path between said cathode and anode, a gas filling in said envelope, and separating means substantially completely separating each of said discharge paths from each other, whereby positive ions created by an active anode are not available to supply an inverse current to an idle anode, said separating means comprising an enclosure enclosing each of said anodes, a wall of each of said enclosures being perforated to provide an opening in each of said enclosure walls, means for producing a stream of said gas filling past said openings, and means adjacent each of said openings to produce an aspirator action by said stream tending to evacuate said enclosures.

5. An electrical space discharge device comprising an envelope containing a cathode and a plurality of anodes, each anode spaced from said cathode to provide a separate discharge path between said cathode and anode, a body of vaporizable material adapted to supply a vapor filling to said envelope, surfaces within said envelope upon which said vapor condenses, separating means substantially completely separating each of said discharge paths from each other whereby positive ions created by an active anode are not available to supply an inverse current to an idle anode, said separating means comprising an enclosure enclosing each of said anodes, a wall of each of said enclosures being perforated to provide an opening in each of said enclosure walls, means for producing a stream of said vapor filling past said openings to said condensing surfaces, and means separating and shielding said discharge paths from all of said surfaces upon which said vapor may condense, whereby condensed particles are prevented from entering said discharge paths from said surfaces.

6. An electrical space discharge device comprising an envelope containing a cathode and a plurality of anodes, each anode spaced from said cathode to provide a separate discharge path between said cathode and anode, a body of vaporizable material adapted to supply a vapor filling to said envelope, surfaces within said envelope upon which said vapor condenses, separating means substantially completely separating each of said discharge paths from each other

whereby positive ions created by an active anode are not available to supply an inverse current to an idle anode, said separating means comprising an enclosure enclosing each of said anodes, a wall of each of said enclosures being perforated to provide an opening in each of said enclosure walls, means for producing a stream of said vapor filling past said openings to said condensing surfaces, means adjacent each of said openings to produce an aspirator action by said stream tending to evacuate said enclosures, and means separating and shielding said discharge paths from all of said surfaces upon which said vapor may condense, whereby condensed particles are prevented from entering said discharge paths from said surfaces.

7. An electrical space discharge device comprising an envelope containing a cathode and an anode spaced apart to provide a discharge path between them, a body of vaporizable material adapted to supply a vapor filling to said envelope, a conduit for conducting vapor from said body of vaporizable material past said cathode, said cathode being located in said conduit, the wall of said conduit being perforated to provide an opening for passing the discharge between said cathode and anode, said conduit extending beyond the active surfaces of said cathode, shielding means for the exhaust end of said conduit for preventing condensed particles of said vaporizable material from entering said conduit through said exhaust end, and means surrounding said anode for preventing condensed particles of said vaporizable material from reaching said anode.

8. An electrical space discharge device comprising an envelope containing a cathode and an anode spaced apart to provide a discharge path between them, a body of vaporizable material adapted to supply a vapor filling to said envelope, a conduit for conducting vapor from said body of vaporizable material past said cathode, said cathode being located in said conduit, the wall of said conduit being perforated to provide an opening for passing the discharge between said cathode and anode, said conduit extending beyond the active surfaces of said cathode, the exhaust end of said conduit being located at a sufficiently high level in said envelope that condensed or splashed particles of said vaporizable material cannot enter said exhaust end, and means surrounding said anode for preventing condensed particles of said vaporizable material from reaching said anode.

9. An electrical space discharge device comprising an envelope containing a cathode and an anode spaced apart to provide a discharge path between them, a gas filling in said envelope, an enclosure enclosing said anode, a conduit for conducting a stream of said gas past said cathode, said cathode being located in said conduit, the wall of said conduit being perforated to provide an opening therein communicating with the interior of said enclosure for passing the discharge between said cathode and anode, the wall of said conduit below said opening being indented to provide a louvre for producing an aspirator action by said stream tending to evacuate said enclosure.

10. An electrical space discharge device comprising an envelope containing a cathode and a plurality of anodes, each anode spaced from said cathode to provide a separate discharge path between said cathode and anode, a gas filling in said envelope, means for restricting the discharge from each anode to a different restricted part of

said cathode, said cathode supplying from each of said restricted parts thereof sufficient thermionic emission to supply the maximum discharge to the associated anode which the device is designed to carry, and separating means for substantially completely separating each of said discharge paths from each other, whereby positive ions created by an active anode are not available to supply an inverse current to an idle anode.

11. An electrical space discharge device comprising an envelope containing a cathode and a plurality of anodes, each anode spaced from said cathode to provide a separate discharge path between said cathode and anode, a gas filling in said envelope, means for restricting the discharge from each anode to a different restricted part of said cathode, said cathode supplying from each of said restricted parts thereof sufficient thermionic emission to supply the maximum discharge to the associated anode which the device is designed to carry, and separating means for separating each of said discharge paths from each other, comprising separate enclosure means enclosing each anode and communicating with the restricted part of said cathode associated with the respective anode.

12. An electrical space discharge device comprising an envelope containing a cathode and an anode spaced apart to provide a discharge path between them, a body of vaporizable material adapted to supply a vapor filling to said envelope, surfaces within said envelope upon which said vapor condenses, means for conducting said vapor through said discharge path to said condensing surfaces, and means separating and shielding said discharge path from all of said surfaces upon which said vapor may condense, whereby condensed particles are prevented from entering said discharge path from said surfaces.

13. An electrical space discharge device comprising an envelope containing a cathode and a plurality of anodes, each anode spaced from said cathode to provide a separate discharge path between said cathode and anode, a body of vaporizable material adapted to supply a vapor filling to said envelope, surfaces within said envelope upon which said vapor condenses, means for conducting said vapor through said discharge path to said condensing surfaces, and means separating and shielding said discharge paths from all of said surfaces upon which said vapor may condense, whereby condensed particles are prevented from entering said discharge paths from said surfaces.

rating and shielding said discharge paths from all of said surfaces upon which said vapor may condense, whereby condensed particles are prevented from entering said discharge paths from said surfaces.

14. An electrical space discharge device comprising an envelope containing a cathode and an anode spaced apart to provide a discharge path between them, a body of vaporizable material adapted to supply a vapor filling to said envelope, a conduit for conducting vapor from said body of vaporizable material past said cathode, an opening in the wall of said conduit for passing the discharge between said cathode and anode, surfaces within said envelope upon which said vapor condenses, and means separating and shielding said discharge path from all of said surfaces upon which said vapor may condense, whereby condensed particles are prevented from entering said discharge path from said surfaces.

15. An electrical space discharge device comprising an envelope containing a cathode and a plurality of anodes, each anode spaced from said cathode to provide a separate discharge path between said cathode and anode, a body of vaporizable material adapted to supply a vapor filling to said envelope, a conduit for conducting vapor from said body of vaporizable material past said cathode, openings in the wall of said conduit for passing discharges between said cathode and anodes, surfaces within said envelope upon which said vapor condenses, and means separating and shielding said discharge paths from all of said surfaces upon which said vapor may condense, whereby condensed particles are prevented from entering said discharge paths from said surfaces.

16. An electrical space discharge device comprising an envelope containing a cathode and an anode spaced apart to provide a discharge path between them, vaporizable material adapted to supply a vapor filling to said envelope, surfaces within said envelope upon which said vapor may condense, and means shielding said discharge path from all of said surfaces upon which said vapor may condense, whereby condensed particles are prevented from entering said discharge path from said surfaces.

PERCY L. SPENCER.