Aug. 10, 1937. J. D. LE VAN 2,089,654

ELECTRICAL DISCHARGE DEVICE

Filed July 30, 1931 2 Sheets-Sheet 1

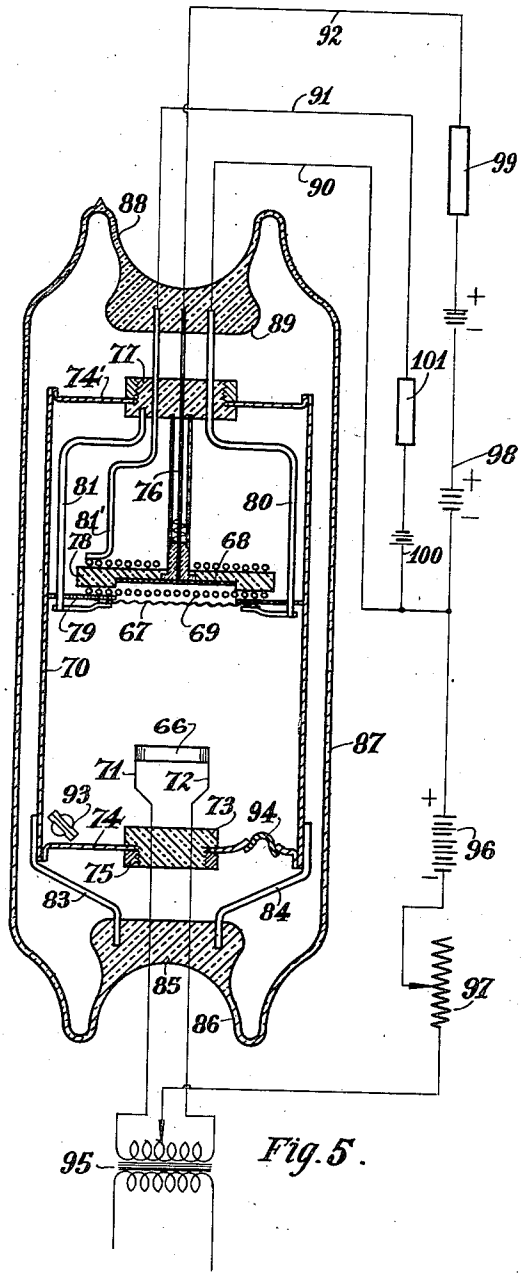


Fig. 5.

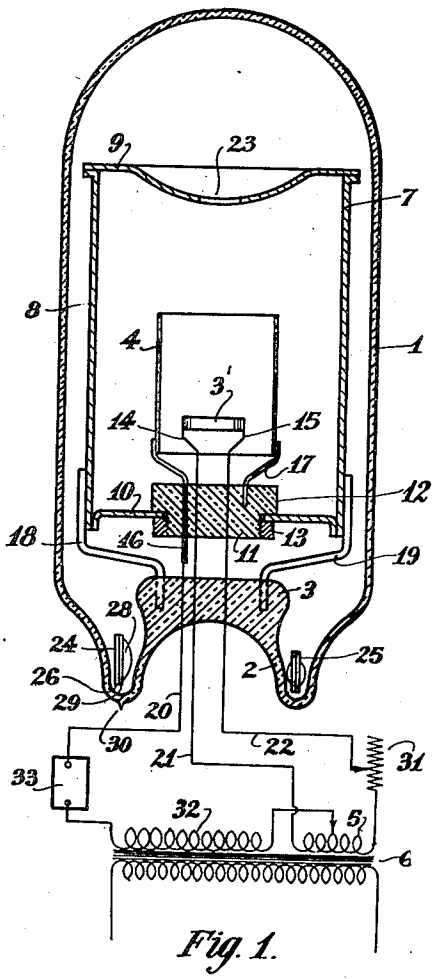


Fig. 1.

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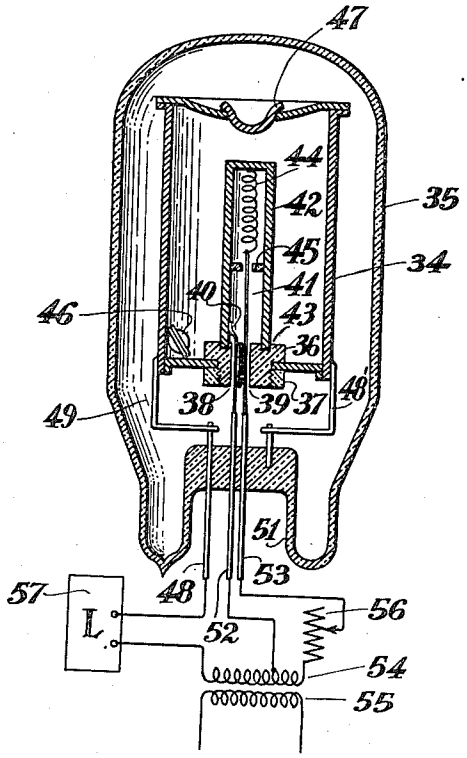


Fig. 3.

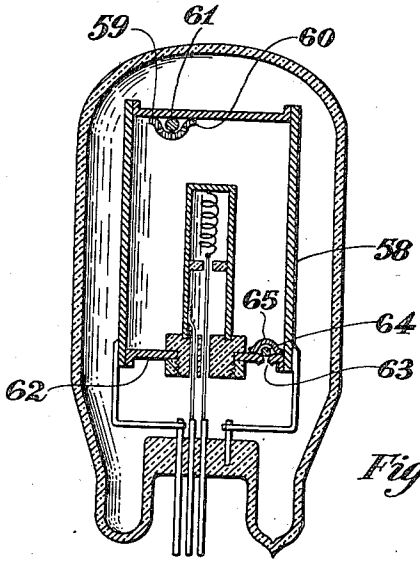


Fig. 4.

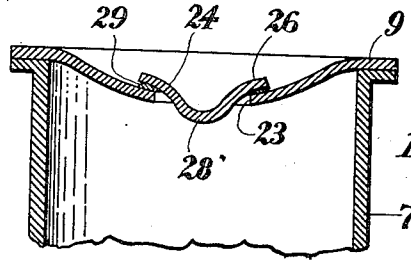


Fig. 2.

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Patented Aug. 10, 1937 2,089,654

UNITED STATES PATENT OFFICE

2,089,654

ELECTRICAL DISCHARGE DEVICE

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Application July 30, 1931, Serial No. 554,013

13 Claims. (Cl. 250—27.5)

This invention relates to electrical discharge devices, and it has special relation to devices in which a discharge is maintained by the electrodes enclosed in a hermetically-sealed, gas or vapor-filled vessel.

Among the objects of the invention is the provision of such discharge devices having a hermetically-sealed, evacuated envelope within which is placed a hermetically-sealed container surrounding the discharge space and containing a gas or vapor.

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

Fig. 1 is a vertical section of a tube embodying my invention, the tube being shown at one stage in its construction;

Fig. 2 is an enlarged sectional view of the upper part of the hollow container shown in Fig. 1, said enlarged view showing the completed form;

Fig. 3 is similar to Fig. 1, showing a modified embodiment of my invention;

Fig. 4 shows a different arrangement for introducing vapors into a tube embodying my invention; and

Fig. 5 shows my invention as applied to a device in which the discharge between two electrodes is controlled by a third electrode.

In a device in which an electrical discharge is maintained in a vapor, it is often desirable to operate that device with the vapor pressure at a fairly high point. The operation of such devices at high vapor pressure generally gives improved operation. For example, when a discharge is maintained between two electrodes in a vapor, the voltage drop between said electrodes ordinarily decreases with the increase in vapor pressure. Also, increased vapor pressure results in a greater ionization of the vapor, and consequently an increase in the number of ions in the discharge space. This increase in ions decreases the space charge between the electrodes. The operation of said discharge device at high vapor pressure generally results in improved operation and higher efficiency.

The vapor pressure is dependent upon the temperature of the coolest portion of the space in which said vapor exists. Therefore, in order to obtain a high pressure, it is necessary to maintain the entire discharge space at a comparatively high temperature. In accordance with my invention, I accomplish this and other results by enclosing the vapor in a hermetically-sealed container placed in an evacuated envelope. This container is preferably but not necessarily opaque.

The device, as shown in Fig. 1, includes a hermetically-sealed envelope 1 which may be of glass. The envelope 1 is provided with a reentrant stem 2, having press 3 in its upper end. The device is provided with an anode 4 and a cathode 3', which are adapted to maintain an electrical discharge between them. This discharge is to be maintained in some gaseous or vaporous atmosphere. I find that vapors of alkali metals are particularly effective although various other gases and vapors may be used as the atmosphere in which the discharge takes place. Of the alkali metal vapors, caesium and rubidium are particularly desirable because of their low ionization and resonance voltages. I enclose the discharge space by surrounding it with a container 7, which may be constructed of some thin metal, such as iron, nickel, and the like. This container comprises a tubular portion 8, provided with a top plate 9 and a bottom plate 10. Both of these plates are joined to the tubular portion 8 by means of welding or some other similar process. The joint between the plates 9 and 10 and tubular portion 8 is made hermetic. The bottom plate 10 is provided with an opening through which passes the reduced portion 11 of an insulating bushing 12. An insulating nut 13 is threaded onto the outer end of the reduced portion 11. This insulating assembly is maintained on the plate 10 by clamping said plate between the head of the bushing 12 and the nut 13. This insulating assembly is made of some suitable insulating substance, such as lava, alundum (Al_2O_3), isolantite, magnesia, etc., which is not readily attacked by alkali metal vapors. A cement is placed between the plate 10 and the insulating assembly in order to make a hermetic seal between them. I have found that a cement made of magnesium oxide and sodium silicate is satisfactory. The cathode 3' is supported within the container 7 by means of a pair of support wires 14 and 15, which pass through openings in the bushing 12. These openings are made approximately the same size as the wires, and such a cement as mentioned above is used to form a hermetic seal between these wires and bushing 12. The anode 4 is supported within the container 7 by means of a pair of support wires 16 and 17. The wire 16 passes through the insulating bushing 12, and is sealed therein in the same manner as are the wires 14 and 15. The wire 17, however,

is merely sealed into a recess in the top of the bushing 12. The container 7, together with its electrode assembly, is carried from the press 3 by means of two supporting standards 18 and 19, sealed in said press 3. The wires 14, 15 and 16 are connected to lead-in wires 20, 21 and 22 respectively, also sealed into the press 3.

In order to provide the interior of the container 7 with vapors, an opening 23 is left in the top plate 9. This plate is dish-shaped, and said opening is provided in the bottom of the concavity. When the various parts are assembled within the envelope 1, a cap 24 and a capsule 25 are also placed within said envelope. The cap 24 is made of some magnetic metal, such as nickel, and is formed with a flange 26 and a depressed central portion 28. On the under side of the flange is placed a ring 29 of an alloy having a melting point which is above the temperature at which the tube is adapted to be operated. I have found that such an alloy may be one consisting of 73% silver and 27% copper, which alloy melts at about 780° C. The capsule 25 is also made of a magnetic material, and contains a mixture which evolves caesium upon heating. This mixture may be, for example, caesium chloride and calcium or caesium dichromate and silicon.

The parts of the tube are originally assembled, as shown in Fig. 1, with the exception that the usual exhaust tube, which is provided at some point, such as 30, on the envelope 1, is left open and also the connections shown in diagrammatic form in the lower portion of Fig. 1, are omitted. The exhaust tube is connected to an evacuation pump, and the envelope is pumped out in the usual manner. During the pumping, the container 7, together with the various parts carried by it, are heated in order to drive off the occluded gases therefrom. This may be done by inducing high frequency currents in these parts by surrounding them with a coil carrying high frequency currents. During this heating process, the cap 24 and the capsule 25 are kept outside of the container 7 at some such point as the bottom of the envelope 1, as shown in Fig. 1. The gases which are driven from the various metal parts so heated are pumped out through the exhaust tube. The capsule 25 is then lifted by means of a magnet and dropped through the opening 23 into the interior 27. The cap 24 is then lifted by a magnet and dropped onto the plate 9. Due to the dish-shaped configuration of plate 9, the cap settles naturally into the opening 23, as shown in Fig. 2. The top of the container 7 is then heated, for example, by induction as explained above. This heating is carried on until the temperature rises sufficiently to melt the alloy 29. This alloy, upon melting, forms a hermetic seal between the plate 9 and the cap 24. Since the envelope 1 is maintained in an upright position, the capsule 25 falls naturally to the bottom of container 7. After the cap 24 is sealed in the opening 23, the bottom of container 7 is heated in a similar manner until the temperature of the capsule 25 rises to a point sufficient to liberate caesium from the mixture contained therein. The pumping through the exhaust tube is preferably continued during the melting of the alloy 29 and the heating of the capsule 25 in order that any occluded gases which are given off into the envelope 1 during these steps may be pumped out. After the above steps have been completed, the envelope is sealed by sealing the exhaust tube. It is possible, however, to seal the envelope 1 at any time after the metal parts are first freed of occluded gases and the envelope 1 evacuated. In the final form of the tube, we have the container 7 within a vacuum, containing free caesium or caesium vapor and enclosing the anode 4 and cathode 3'.

The cathode 3' may be in the form of a filament of some metal, such as nickel, tantalum, tungsten, or molybdenum, which is coated with some material to make it a good emitter of electrons. I have found that a very satisfactory coating is obtained by oxidizing the surface of the filament before the caesium is introduced. Upon the liberation of caesium, the oxide coating causes part of the caesium to deposit on the surface of the filament. This coating causes large numbers of electrons to be emitted at comparatively low temperatures. Other coatings, such as barium or strontium oxide, may also be used. The tube shown in Fig. 1 is connected to function as a rectifier, and is provided with some suitable circuit, such as is shown in Fig. 1. The filament 3 is provided with heating current from a secondary 5 of a transformer 6. The amount of current in the filament may be controlled by a regulating resistance 31. A connection from the midpoint of the heating transformer 5 goes to another secondary winding 32 of the transformer 6 through an output device 33 to the lead-in wire 20, which is connected to the anode 4. The output device 33 may be any kind of a load to which it may be desired to furnish direct current.

The current from the secondary 5 heats the cathode 3' to a point at which it emits electrons. During the half of the alternating cycling in which the anode 4 is positive, electrons coming off the cathode 3' will be attracted toward the anode 4. The electrons leaving the cathode collide with caesium atoms and give up part of their energy. The caesium atoms are excited or ionized, depending on the energy of the colliding particles. The excited atoms are very easily ionized by the absorption of slight additional amounts of energy either from collisions or absorptions of radiations. If an excited atom is not ionized in a short time, it may lose by radiation the energy which it has absorbed. At the high vapor pressure which I use, the density of the vapor is high so that the radiation so emitted is reabsorbed by other atoms which will either be excited or ionized, due to such absorption. Since in the exemplification shown, the container 7 is entirely opaque, it acts as a heat and light shield, and any radiations which are not absorbed by vapor atoms will be absorbed by the walls of the container 7 and converted into heat, thereby tending to maintain the temperature and vapor pressure of the vapor at a high value. Thus the vapor will be highly ionized, and in the space between the cathode and anode large numbers of electrons and positive ions will exist. The positive ions neutralize the space charge due to the negative electrons, and give a very low voltage drop, even at comparatively high values of current. Upon reversal of the voltage applied to the anode 4, practically no current will pass inasmuch as the anode 4 does not emit any electrons. Thus the current passing through the output device 33 will be unidirectional.

Since the container 7 is in a vacuum, there will be no loss of heat by conduction through the space surrounding it, and, therefore, the only loss of heat liberated by the discharge will be through radiation or conduction along the lead-in wires, which losses are comparatively slight. The container 7, by acting as a heat shield, causes

the temperature of the container to rise to an elevated temperature, which in the embodiment shown is about 150° C. At this temperature there will be an appreciable vapor pressure of caesium, and the voltage drop will be near the minimum.

The caesium would attack the ordinary glass container at the above temperature, but, since it is in such an enclosure as described, this disadvantage is eliminated. If caesium were to condense on the bushing 12, a conductive path would be formed along the surface of said bushing and a short circuit between the cathode and anode would occur. This is prevented by keeping the bushing hotter than the coolest portion of the discharge vapor. This results from the fact that the bushing 12 is closer to the cathode 3' than some parts of the envelope 7. Since all condensation of the caesium takes place at the coolest portion of the discharge space, it is clear that no caesium will condense on the bushing 12. In addition, the cathode 3' is placed sufficiently distant from the bushing 12, so that the bushing is not at a temperature sufficiently high for the caesium to attack it directly.

By placing the container 7 within an evacuated envelope 1, various advantages are obtained. As pointed out above, the vacuum insulates the container against the loss of heat by conduction. It is difficult to construct such a container as described and make all of the joints sufficiently strong so as to be absolutely hermetic at high pressures. When the tube is inactive and allowed to cool, the pressure within the container 7 drops to a low value. If the container were not in a vacuum but were left exposed to atmospheric pressure, an appreciable amount of air would leak through the various joints. This air would destroy the usefulness of the tube. By enclosing the container in a hermetically-sealed envelope, the pressure in the container will at no time be less than the pressure in the envelope. Thus, there will be no tendency for any foreign gas in the envelope to leak into the container. Under operating conditions, the pressure within the container rises to a point above that in the envelope, whereupon there is some tendency for the caesium to leak out into the envelope. However, since the spaces are so small and since the caesium would tend to condense upon the walls of these spaces in passing through them, the rate at which caesium can diffuse out from the container 7 is negligible. Due to the fact that the container 7 is in an evacuated space, it can be made of a light, thin metal, since it is not subjected to any considerable external pressure.

Instead of using a separate container to enclose the discharge space, the electrodes themselves can be made to perform that function. Such an arrangement is shown in Fig. 3. In Fig. 3 the container is formed by a hollow anode 34, supported within the sealed glass envelope 35. This anode is constructed exactly the same as the container 7 shown in Fig. 1, and carries an insulating bushing 36 similar to the bushing 12. A sealing cement, as described above, is used to make the connection between the anode and the insulating bushing 36 hermetic. The bushing is provided with two passages 38 and 39, through which pass two lead-in wires 40 and 41. The passages 38 and 39 are somewhat larger than the wires 40 and 41. A hollow cathode 42 is cemented into an annular groove to make the connection between the cathode and the bushing 36 gas and vapor-tight. Thus the cathode serves to form part of the hermetic seal between the discharge space and the interior of the envelope 35.

The cathode is made of thin metal, such as, for example iron, nickel, tantalum, tungsten, or molybdenum, and provided with a coating to increase the electron emission. This coating may be such as described for the cathode 3' in Fig. 1. In order to raise the temperature of the cathode 42 to the requisite point, a heating filament 44 is placed within said cathode. One end of the filament is connected to the lead-in wire 41, and the other end is connected to the cathode. The filament 44 is placed in the upper end of the cathode. This arrangement keeps the bushing 36 hotter than the coolest portion of the vapor enclosure, but, due to the fact that the filament is in the opposite end of the cathode, the bushing 36 is not hot enough to be attacked by alkali metal vapors. An insulating spacer 45 may be used to center the upper end of the wire 41 within the cathode.

The wire 40 is welded to the interior of the cathode 42. The anode 34 has a wire 49 welded to it. This wire 49 is welded to a lead-in wire 48, sealed in the press 50 on the reentrant stem 51 of the envelope 35. An additional wire 48' also sealed in the press 50 cooperates with the wire 49 to support the anode. The wires 40 and 41 are connected respectively to two lead-in wires 52 and 53, also sealed in the press 50. The envelope 35 is evacuated, and the anode 34 is filled with caesium vapor from a capsule 46 and sealed with a cap 47 in a manner similar to that described for Fig. 1.

Since the interior of the cathode 42 is connected to the interior of the envelope 35 by means of the passages 38 and 39, the filament 44 is operated outside of the caesium vapor and in the evacuated region. Thus, any desired voltage may be used to heat the filament, and the possibility of a discharge forming across the filament leads due to the presence of caesium vapor is eliminated. Such an arrangement enables the cathode and filament to have an exceptionally long life.

One of the circuits with which the tube may be used is shown in Fig. 3. The filament is furnished with heating current from a portion of the secondary 54 of a transformer. A regulating resistance 56 may be used to control the amount of current in the filament 44. Another portion of the secondary 54 is used to impress an alternating potential between the wires 48 and 52, and consequently between the anode 34 and the cathode 42. A load 57 is connected in series in the cathode-anode circuit. The current in the filament 44 heats the cathode 42 to a point at which it emits electrons. The operation of the device is exactly the same as described in Fig. 1.

I have constructed a rectifier containing caesium vapor, in accordance with the above description, which operated with a voltage drop as low as .1 volt while passing 5 amperes. This rectifier was operated with a back voltage of 500 volts.

The modification disclosed in Fig. 4 involves a somewhat different means for sealing up the caesium vapor within the anode. The tube shown in Fig. 4 is exactly the same as that described in Fig. 3, except for the form of the anode. The anode 58 in Fig. 4 has its top plate 59 without any opening such as that provided in the top plate in Fig. 3. To this top plate is welded the cap 60, which encloses a caesium pill 61. This pill is composed of a mixture which evolves caesium on heating. The bottom plate 62 of the anode 58 is provided with a small opening 63.

Immediately above the opening 63 is a small piece of alloy 64. This alloy is preferably the same as that employed for the ring 29 as described for Figs. 1 and 2. The alloy 64 is maintained in place by a small strip 65 welded to the plate 62. The alloy 64 is maintained in place very loosely. During the pumping of the envelope, the structure within the envelope is heated to drive off occluded gases, but the heating is so controlled that the temperature of the anode is not allowed to rise to a point high enough to evolve caesium from the caesium pill or to fuse the alloy 36. When the envelope is completely evacuated, the bottom of the anode is heated, and the temperature of that portion of the anode is allowed to rise to a point sufficient to melt the alloy 64. Upon melting, the alloy runs into the small hole 63 which is small enough to prevent the alloy from running through said hole. The alloy is then allowed to cool, and in so doing seals up the anode 58. The top of the anode is then heated and the temperature of that portion of the anode is allowed to rise to a point sufficient to evolve caesium from the caesium pill. The envelope is then sealed up. Thus, the final form of the tube in Fig. 4 exhibits exactly the same properties as does the tube disclosed in Figs. 1 and 3.

Although I have described my invention embodied in a rectifier, yet it has application to any device in which an electrical discharge occurs in a vapor. For example, Fig. 5 shows a device in which a control electrode is used to control the discharge between two other electrodes. The arrangement of the various electrodes is similar to that described and claimed in my Patent No. 1,962,159, dated June 12, 1934. An ionizing electrical discharge is adapted to be maintained between a filament 66 and a screen electrode 67. An anode 68, which is maintained at a positive potential with respect to the screen electrode 67, is adapted to attract electrons which pass through said screen from the ionizing discharge space between the electrodes 66 and 67. A control electrode 69 is interposed between the electrodes 67 and 68 to control the amount of current passing between these latter two electrodes. The spacing between the electrodes 67 and 68 is made of the order of the mean free path of the molecules in the vapor under the pressure conditions existing in the tube under operating conditions. The electrode system is operated in some gaseous or vaporous atmosphere which is ionized by the discharge between the electrodes 66 and 67. The entire discharge space and the electrode system is enclosed in a hermetically-sealed container 70 in a manner similar to that described for Fig. 1. The filament 66 is carried by two lead-in wires 71 and 72, which are hermetically sealed in an insulating bushing 73. This bushing 73 is similar to the bushing 12 and in like manner is sealed to the bottom plate 74 of the container 70 by the insulating nut 75 and a sealing cement. The anode 68 is carried at one end of a rod 76, hermetically sealed in an insulating bushing 77, which also is similar to the bushing 12. The anode 68 is placed in a recess in an insulating block 78. The control electrode 69 is in the form of a thin wire wound around the block 78. An insulating sleeve surrounds the rod 76 from the bushing 77 to the block 78. An insulating disk 79 extends the full width of the container 70, and forms a partition separating the upper and lower parts of the container 70. This disk is placed between the electrodes 69 and 67, but has a central opening therein through which the electron stream can pass. Two support wires 80 and 81 are also hermetically sealed in the insulating bushing 77. These two support wires project through the disk 79, and are connected to the screen electrode 67. A lead-in wire 81' connected to the control electrode 69 is also hermetically sealed in the insulating bushing 77. The insulating bushing 77 is hermetically sealed to the top plate 74' of the container 70 in the same manner as is the bushing 73. The container 70, together with the electrode arrangement mounted therein, is carried by two support standards 83 and 84, sealed in a press 85 on the upper end of the reentrant stem 86 of a hermetically-sealed glass envelope 87. The lead-in wires 71 and 72 are provided with extensions which are also sealed in the press 85. At the opposite end of the envelope 87 is a second reentrant stem 88, having a press 89. Three lead-in wires 90, 91, and 92, sealed in said press, are connected respectively to the three conductors 80, 81', and 76. The interior of the envelope 87 is evacuated in a manner similar to that described for Fig. 1. The interior of the container 70 is supplied with vapors from a capsule 93 and sealed by a cap 94, also in the manner as described for Fig. 1.

In Fig. 5 is shown one of the circuits with which the tube shown in that figure can be used. The filament 66 is connected to a winding of the supply transformer 95 so as to be heated to a temperature at which the tube is in an electron-emitting condition. Between the midpoint of the filament transformer 95 and the screen electrode 67 is connected a suitable source of current, for instance, a battery 96, the screen electrode being connected to the positive terminal of the source 96. A resistance 97 serves to control the current flow. A discharge occurs between the screen electrode 67 and the filament 66, resulting in intense ionization of the vapor in the discharge space, in accordance with the explanation as given for Fig. 1. Between the lead 80 from the screen electrode 67 and the anode 68 is connected an anode circuit, including a source of anode voltage, for instance, a battery 98, having its positive terminal connected on the anode side of the circuit and an output device 99. The input circuit of the tube is formed by connecting, between the lead 90 for the screen electrode 67 and the control electrode 69, a source of biasing voltage, for instance, in the form of a battery 100 and an input device 101 which may be, for example, a phonograph pickup coil or the like.

Upon operation of the tube, an intense ionization will occur between the electrodes 66 and 67. Thus, there exists in this space a large supply of electrons which, passing through the screen electrode 67, serve as the source of electrons for the current flowing between the electrodes 67 and 68. These electrons, after passing through the screen, come under the influence of the field produced by the battery 98 and are attracted toward the positive anode 68. A few positive ions are created between the electrodes 67 and 68, probably by electrons passing through the screen 67 from the space between the electrodes 66 and 67 with enough velocity to cause ionization. These ions decrease the space charge between the electrodes 67 and 68. However, since the spacing between these latter two electrodes is of the order of the mean free path of the vapor molecules, a high voltage can be impressed between them without causing a substantial ionization by

collision in the space between the said electrodes. The space current between these electrodes is readily controlled by the charge applied to the control grid 69, as in high-vacuum, electron tubes. Thus, the input device will impress a variable control potential upon the control grid 69, resulting in amplified variations in the current flowing in the output device 99. A more complete description of the type of tube, as shown in Fig. 5, is to be had in my above-mentioned Patent No. 1,962,159.

In the exemplifications described above, the ionizing discharge between the electrodes was maintained by means of a thermionic cathode. However, my invention is equally applicable to tubes in which the discharge is maintained by a glow discharge between two electrodes, such, for example, as are shown in the patents to Smith, No. 1,617,179 and No. 1,617,180, and the patent to Donle, No. 1,731,889.

The invention is not limited to the particular details of construction, materials, or processes described above, as many equivalents 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.

Having described my invention, I claim:

1. An electrical discharge device, including an ionizable atmosphere within which an electrical discharge is to be maintained, a sealed container enclosing said atmosphere, said container having minute openings through which gas may be able to pass and a sealed envelope enclosing said container, the pressure within said envelope being at no time greater than the pressure within the said container whereby leakage of gas into said container is prevented.

2. An electrical discharge device, including an ionizable atmosphere within which an electrical discharge is to be maintained, a substantially sealed container enclosing said atmosphere, and a sealed envelope within said container, the pressure within said envelope being less than the pressure within said container.

3. An electrical discharge device, including an ionizable atmosphere within which an electrical discharge is to be maintained, an opaque substantially sealed container enclosing said atmosphere, and a sealed evacuated envelope enclosing said container, the pressure within said envelope being less than the pressure within said container.

4. An electrical discharge device, including an ionizable atmosphere, two electrons adapted to maintain an ionizing discharge in said atmosphere, said electrodes being formed so as to form a sealed chamber enclosing said atmosphere, and a sealed evacuated envelope enclosing said electrodes, the pressure within said envelope being less than the pressure within said container.

5. An electrical discharge device, including an ionizable atmosphere, a sealed container enclosing said atmosphere, means to maintain an ionizing discharge in said atmosphere, said means including a thermionic cathode, a sealed envelope enclosing said container, and means for heating said cathode, said means being located within said envelope but outside of said container, the pressure within said envelope being less than the pressure within said container.

6. An electrical discharge device, including a hollow anode, a cathode insulated from said anode, said electrodes being arranged so as to form a sealed container, an ionizable atmosphere within said container, a sealed glass envelope enclosing said container, and a heating element for said cathode, said element being within said envelope but outside of said container.

7. An electrical discharge device, including a sealed metal container, a discharge supporting atmosphere comprising an alkali metal vapor within said container at a pressure sufficiently high to produce sufficient ionization to carry the main discharge through said tube, means for maintaining an electrical discharge in said vapor, and a sealed glass envelope enclosing said container, said envelope containing substantially none of said vapor outside of said container.

8. An electrical discharge device, including an ionizable atmosphere, a container enclosing said atmosphere, said container having an aperture, said aperture being sealed by an easily fusible alloy, said alloy having a melting point sufficiently high so that it will not melt under operating conditions of said device, and a sealed envelope enclosing said container.

9. An electrical discharge device, including an ionizable atmosphere, a hollow container enclosing said atmosphere, the upper end of said container being concave, an aperture at substantially the bottom of said concavity, a cap for closing said aperture, a fusible alloy for sealing said cap to said upper end, and a sealed evacuated envelope enclosing said container.

10. An electrical discharge device, including an alkali metal vapor, a sealed container enclosing said vapor, an insulating bushing sealed in one end of said container, a hollow thermionic cathode carried by said insulator, a heating filament within said cathode, all parts of said filament being spaced from said bushing, and a sealed glass envelope enclosing said container.

11. The method of introducing an ionizable atmosphere into an electrical discharge device, comprising an envelope enclosing a container within which a discharge is adapted to be maintained, which method consists in evacuating said envelope and container, introducing a material which liberates the ionizable atmosphere upon heating into said container, sealing said container, liberating the ionizable atmosphere from said material by heating, and sealing said envelope any time after the evacuation is completed.

12. An electrical discharge device, including a discharge supporting atmosphere including caesium vapor, a sealed metal container enclosing said caesium vapor at a pressure sufficiently high to produce sufficient ionization to carry the main discharge through said tube, a sealed glass envelope enclosing said container, and means for maintaining an ionizing discharge in said vapor, said envelope containing substantially none of said caesium vapor outside of said container.

13. An electrical discharge device, including an ionizable atmosphere within which an electrical discharge is adapted to be maintained, an opaque sealed container enclosing said atmosphere, said container comprising a metallically conducting material, and a sealed evacuated envelope enclosing said container, the pressure within said envelope being less than the pressure within said container.

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