Dec. 8, 1942. V. L. RONCI ET AL 2,304,657

ELECTRON DISCHARGE DEVICE

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FIG. 2

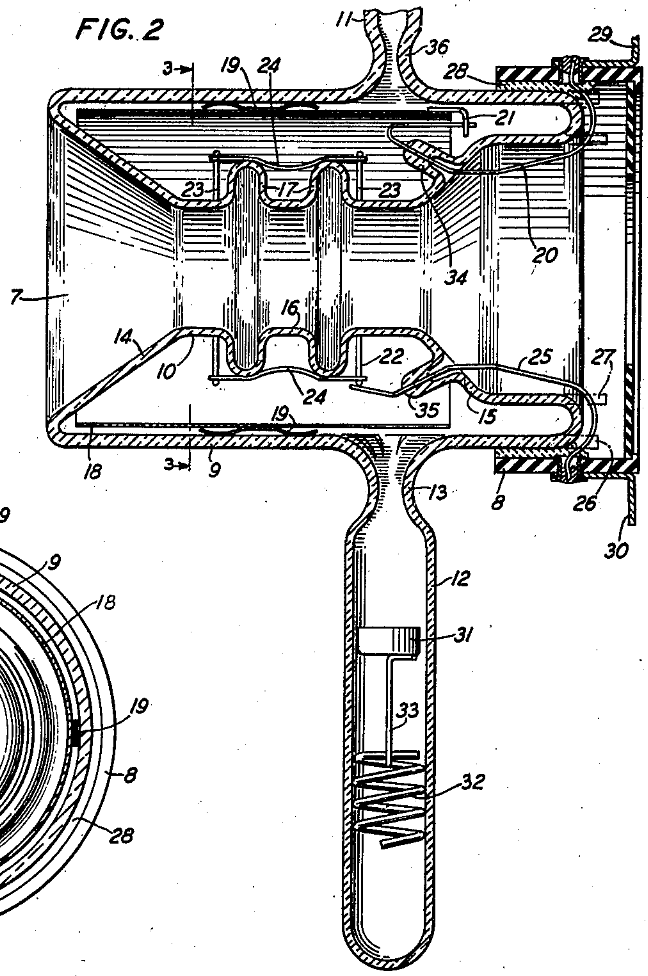

FIG. 3

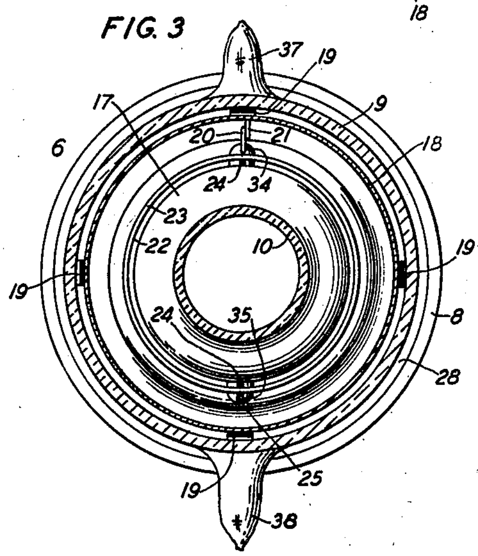

FIG. 1

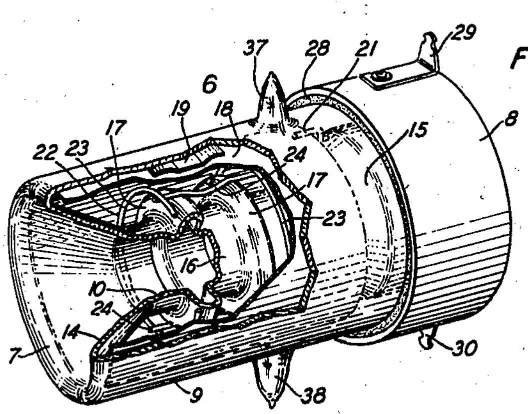

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FIG. 4

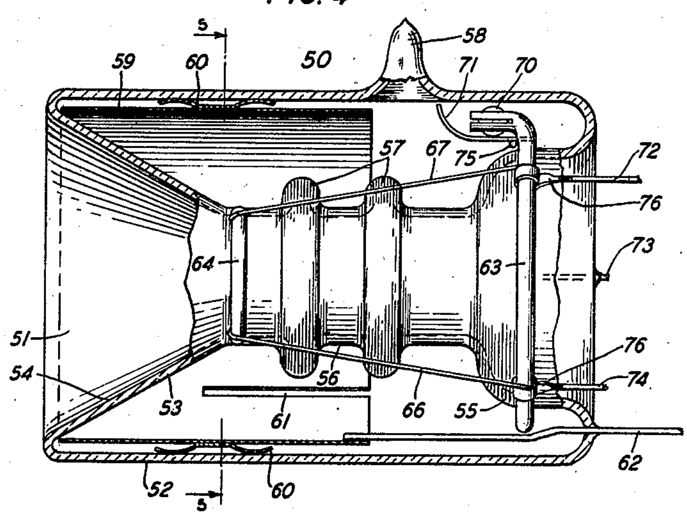
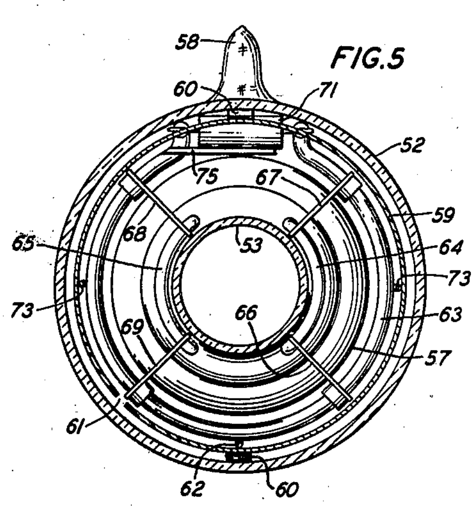


FIG. 5



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UNITED STATES PATENT OFFICE

2,304,657

ELECTRON DISCHARGE DEVICE

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Application December 28, 1939, Serial No. 311,280

13 Claims. (Cl. 250—165)

This invention relates to electron discharge devices and more particularly to a photoelectric tube.

An object of the invention is to provide an improved electron discharge device comprising an annular container.

In an example of practice illustrative of the invention a tubular cathode and a squirrel-cage anode are supported in operative relationship in an annular glass container having generally cylindrical outer and inner walls sealed together at their ends. The cathode is spring supported from the inner surface of the outer wall member of the container coaxial therewith and suitably treated to render the inner surface photoelectrically sensitive. The anode is supported by the bars of the squirrel cage on circumferential corrugations extending around the inner wall of the container intermediate the two flared ends thereof. One flared end is conical and serves as the window through which light is admitted to energize the cathode. The other flared end carries the lead-in wires for the cathode and anode.

In fabricating or assembling this example of practice the inner and outer walls are formed separately of lime glass. The inner wall comprising the flared end portions and the intermediate corregated portion may be built up of separate sections sealed together, or it may be formed as a unit in a mold with compressed air. The lead-in wires are sealed through the lime glass of the inner wall by means of lead glass beads first fused on the lead-in wires, the lead glass beads being inserted in holes through the lime glass and sealed to the lime glass. The anode is formed around the inner wall and electrically welded to its lead-in conductor. The inner wall is then placed coaxially within the outer wall and the conically flared end sealed to the outer wall. Since the larger end of the flared portion carrying the lead-in wires is slightly smaller than the outer wall, a small circular opening remains after the first seal is completed. Through this opening the tubular cathode of silver is slipped to a position such that its entering end is very close to this first seal. With a special set of welding electrodes the cathode lead-in wire is then welded to a short wire projection previously welded to the cathode. The small opening is finally closed by sealing the inner and outer walls together at that point. Caesium and oxygen are used to sensitize the silver cathode. The caesium is produced by chemical reaction in a side tube during the sensitizing process. The container is connected through another side tube to the vacuum pumping station.

The great advantage of this method of fabricating the tube is that the glass seals are made at such times and in such ways as not to injure the cathode by excessive heating. The seal between the outer wall and the conically flared portion of the inner wall is made before the cathode is placed in position with an end close to the seal, whereby injury to the cathode by heat employed in the sealing operation is avoided. Due to the flare at the opposite end of the inner wall only a relatively small amount of glass needs to be heated to finally seal this small opening. Thus, the cathode may be made almost as long as the inside of the completed container and still not be injured during the final sealing operation. The circumferential corrugations prevent strains in the glass sufficient to rupture the glass after sealing. The conically shaped window permits light from a small source located on the axis of the tube and just beyond the end of the tube to enter the window at an advantageous angle of incidence. Other advantages will be apparent from a consideration of various embodiments of the invention.

In a modified example of practice the pellet containing the caesium producing mixture is mounted within the tube container. The pellet is enclosed in a high resistance metallic capsule connected between the ends of a low resistance open copper ring. This ring carries four springy tungsten wires which in pairs support two sections of nickel wire rings adapted to press against the inner wall near the conical portion when the copper ring and capsule encircle the opposite flared end of the inner wall. These nickel wires and connected structure constitute the anode structure. In this modification both the cathode and anode are inserted through the circular opening between the inner and outer walls after the conically flared end of the inner wall has been sealed to the outer wall.

The invention will now be described more in detail, having reference to the accompanying drawings.

Fig. 1 is a perspective of one embodiment of the invention;

Fig. 2 is a longitudinal section through the axis of the tube of Fig. 1 before the side tubes are sealed off;

Fig. 3 is a cross-section along the line 3—3 of Fig. 2 looking toward the terminal end of the container under the assumption that the side tubes have been sealed off;

Fig. 4 is a partial longitudinal section of a modified embodiment of the invention;

Fig. 5 is a cross-section along the line 5—5 of Fig. 4 looking toward the terminal end of the container.

The same reference characters are used in the several figures to indicate identical elements.

The embodiment illustrated in Figs. 1, 2 and 3 will first be described. This embodiment is a photoelectric tube 6 comprising an evacuated glass container 7 of annular shape mounted on a base 8. The container 7 comprises a cylindrical outer wall member 9 and a generally cylindrical inner wall member 10. The outer wall member 9 is provided with a side tube 11. This tube 11 is provided for connecting the container 7 to the vacuum pumping station during the sensitizing of the cathode and is later sealed off at the constricted portion 36 upon completion of the sensitizing process. The outer wall 9 is also provided with a side tube 12 within which the reactive mixture for producing caesium is placed. This side tube 12 is also sealed off at the constructed portion 13 after the cathode has been sensitized. The inner wall member 10 comprises a conical portion 14, a flared portion 15 and an intermediate portion 16 which last portion is provided with two circumferential corrugations 17 extending around the central portion 16. The lead-in wires for the cathode and anode are sealed through the flared portion 15. The lead wires are sealed to lead glass beads which in turn are sealed to the lime glass of the flare.

The cathode 18 is a thin walled bimetallic tubular member of nickel and silver, the inner surface being of silver of a higher degree of purity. It is frictionally supported from the outer wall member 9 by four spring members 19 which are welded to the convex surface of the cathode 18.

The anode 22 is in the general form of a squirrel cage comprising end rings 23 and connecting bars 24. Any number of bars may be used. Two are illustrated. The anode is made preferably of nickel and the bars 24 are bent as shown to press against the corrugations 17 of the inner wall member 10.

In assembling this tube it is essential that precautions be taken not to overheat the cathode. Overheating would modify the surface structure and interfere with the sensitizing process later to be carried out during the vacuum pumping operation. The structure of this tube and the method of assembling the various components obviates injury to the cathode and still provides a compact and efficient structure.

The outer wall member 9 before assembly is in the form of a hollow lime glass cylinder having side tubes at 11 and 12 attached thereto. The inner wall member 10 is also of lime glass in the form illustrated with the three portions 14, 15 and 16 and the anode 22 assembled thereon. This inner wall member 10 may be formed in any suitable manner as by forming the three portions 14, 15 and 16 separately and sealing them together end to end or by forming the whole inner wall member 10 from a lime glass tube by heating in a form and shaping it with compressed air. The inner wall member 10 with the anode 22 is inserted into the outer wall member 9 coaxially therewith and the outer end of the conical portion 14 is sealed to the corresponding end of the outer wall member 9 by heating. After this operation there remains a small circular aperture between the outer wall member 9 and the flared portion 15. Enough material to finally seal this aperture is provided in the outer wall member and the flare, such material being indicated by the dot-dash extensions 26 and 27 in Fig. 2. The cathode 18 is now slipped through this aperture to a position where one end is almost in contact with the sealed junction between the outer wall member 9 and the conical portion 14. The cathode is spaced from the outer wall member 9 by the springs 19 and held in position frictionally thereby. Had the cathode been in this position when the seal between the outer wall member 9 and the conical portion 14 was made, it would have been injured by overheating. By the method of assembly just described any possible injury is obviated. The cathode lead-in wire 20 is now welded to the intermediate wire 21 by means of special welding electrodes (not shown) inserted through the small aperture through which the cathode is inserted. The final step of closing the container 7 consists in sealing the portion 27 of the flared portion 15 to the portion 26 of the outer wall member 9. Comparatively little glass needs to be heated to make this seal so that the cathode 18 may be positioned much closer to this end of the container than as though the portion 15 were not flared.

After the tube has been sensitized it is mounted on a base 8 which comprises a cylindrical shell of thermoplastic material secured to the container 7 at the terminal end of the container by suitable basing cement 28. The cathode lead-in wire 20 is soldered to the cathode terminal 29 and the anode lead-in wire 25 is soldered to the anode terminal 30.

The seal-off tips 38 and 37 in Fig. 3 remain after the side tube 12 has been sealed off at the constricted portion 13 and the side tube 11 has been sealed off at the constriction 36 after the sensitizing process has been completed. In this particular Fig. 3 is not a true cross-section of Fig. 2.

The caesium for sensitizing the cathode is preferably produced by chemical reaction of a mixture in the form of a so-called caesium pellet. This pellet is mounted in a metallic cup 31 which in turn is connected to a spring 32 by a wire 33. The spring engages the inside walls of the side tube 12 and holds the metallic cup 31 in position by friction. The caesium pellet is caused to react chemically by inductively heating the cup 31 in a well-known manner.

A portion of the cathode 18 opposite the side tube 12 is cut away to permit the caesium to be distilled into the container 7 and deposit on the inner glass wall thereof rather than to strike the cathode directly.

For simplicity of illustration, the side tubes 11 and 12 and the lead-in wire seals 34 and 35 in Figs. 2 and 3 are shown lying in the same plane. Preferably the side tubes are opposite one another as are also the lead-in wire seals but the seals are angularly offset from the side tubes by a few degrees, for example, fifteen degrees. By such offsetting, the caesium, as it is distilled into the container 7, does not strike directly the anode lead-in wire seal 35.

A modified embodiment of the invention will now be described by reference to Figs. 4 and 5. This embodiment is also a photoelectric tube 50 comprising an evacuated container 51 of annular shape. The container 51 comprises a cylindrical outer wall member 52 and a generally cylindrical inner wall member 53. The outer wall member 52 is provided with a side tube 58 shown sealed off. This tube 58 is provided for connecting the container 51 to the vacuum pumping station during the sensitizing of the cathode. The inner wall member 53 comprises a conical portion 54, a flared portion 55 and an intermediate portion 56, which last portion is provided with two circumferential corrugations 57 extending around the central portion 56.

The cathode 59 is a thin walled tubular member similar to cathode 18. It is frictionally supported from the outer wall 52 by two spring members 60 which are welded to the convex surface of the cathode 59. The cathode 59 is also provided with three lead-in wires 62 and 73 which are welded to the cathode and eventually sealed in the glass end wall of the container 51.

In this embodiment the caesium pellet is supported within the container 51. The pellet is contained in a high resistance metallic capsule 70 which is connected between the ends of an open ring 63 of heavy copper wire. The copper wire 63 and capsule 70 together form a closed circuit in which current is electromagnetically induced to heat the capsule and cause chemical reaction of the caesium pellet. Only the capsule 70 is heated to any great extent because the copper wire is of low resistance.

Two pairs of springy tungsten wires 66 and 67 and 68 and 69 are welded to the copper ring 63 in such a way that the other ends would press against the inner wall member 53 with the ring positioned as in Fig. 4. The ends of wires 66 and 67, remote from the copper ring 63, are welded to a section of nickel ring 64 and the corresponding ends of wires 68 and 69 are welded to another similar section of nickel ring 65. The sections 64 and 65 are curved so as to conform to the convex surface of the inner wall member 53 at the place where the intermediate section 56 joins the conical section 54. The ends of wires 66, 67, 68 and 69, which are connected to the copper ring 63, are flattened, wrapped around the copper ring 63 and welded thereto. Sections 64 and 65 may, for convenience, be called the anode because most of the electrons emitted from the cathode are collected on these elements. These anode members are spring supported from the caesium capsule support ring 63 and the whole assembly may be called the anode structure.

The process of assembling the tube 50 is much like that of tube 6 of Fig. 1. The outer wall member 52 before assembly is in the form of a hollow lime glass cylinder having a side tube attached at the position indicated by seal-off tip 58. The inner wall member 53 is also of lime glass in the form illustrated with the three portions 54, 55 and 56. This inner wall member 53 may be formed in the same manner as the inner wall member 10 of Fig. 1. The inner wall member 53 is inserted into the outer wall member 52 coaxially therewith and the outer end of the conical portion 54 is sealed to the corresponding end of the outer wall member by heating. After this operation there remains a small circular aperture between the outer wall member 52 and the flared portion 55. Enough material to finally seal this aperture is provided in the outer wall member 52 and the flared portion 55. The cathode 59 is now slipped through this aperture to a position where one end is almost in contact with the conical portion 54 of the inner wall 53. The cathode is spaced from the outer wall member 52 by springs 60 and held in position frictionally thereby. By the method of assembly just described, any possible injury to the cathode 59 by overheating is obviated. The cathode lead-in wire 62 and two support wires 73 protrude through the aperture. The anode structure is next inserted through this circular aperture by springing the anode sections 64 and 65 apart sufficiently to pass over the flared portion 55 and the corrugations 57. After the copper support wire 63 reaches the position shown in Fig. 4, the anode sections 64 and 65 spring toward each other and press against the portion 56 of the inner wall member 53 by reason of the springy tungsten wires 66 to 69, inclusive. The copper support wire 63 is provided with a lead-in wire 72 and three additional support wires 74. These lead-in and support wires are connected to the copper ring 63 through short sections of nickel wire 76 which, in turn, are wrapped around and welded to the copper ring 63. These lead-in and support wires also protrude through the aperture after the anode structure had been inserted in its proper position. The final step of closing the container 51 consists in sealing the flared portion 55 to the outer wall member 52. During this sealing operation the lead-in wires and support wires which protrude through the aperture, are also sealed to the glass to form vacuum tight seals. The support wires 73 and 74 may be cut off flush with the glass seal, while the lead-in wires 72 and 62 are later connected to the tube base terminals.

It is to be noted that the cathode in the modified embodiment illustrated in Fig. 4 does not extend as close to the finally sealed portion of the container 51 as in the embodiment illustrated in Fig. 2. The caesium capsule, however, in the embodiment illustrated in Fig. 4, is comparatively close to such seal and can be so placed without overheating and prematurely flashing the caesium pellet because comparatively little glass needs to be heated to make this seal and the over-all dimensions of container 51 can be made smaller than as though the portion 55 were not flared.

The cathode 59 is provided with a slit 61 to obviate injurious eddy currents in the cathode due to the magnetic field from the energizing magnet (not shown) positioned to induce heating current in the capsule 70. The form of the capsule may be the same as that disclosed in C. H. Prescott, Jr., Patent 2,097,467 patented November 2, 1937. It may be secured to the ends of the copper ring 63 by inserting the end tabs of the capsule in slits in the ends of the copper ring 63 or by clamping in the manner illustrated in the Prescott patent supra. The use of slits in the ends of the copper ring 63 is preferred because of space conditions.

In order to prevent the hot caesium vapor produced by the chemical reaction of the caesium pellet from coming directly into contact with the cathode as the caesium is evolved and to prevent radiated heat from the capsule from injuring the cathode 59, a nickel shield 71 is provided. This shield is supported from the copper wire ring 63 by means of support wire 75 welded at one end to the shield 71 and at the other end to the copper wire 63.

This completed tube may also be mounted on a base like that shown in Fig. 1.

The cathode may be sensitized in any well-known manner after the tube structure has been fabricated. A preferred method is very similar to that described in Patent No. 2,178,227 of M. S. Glass patented October 31, 1939. The method therein described is modified to take into account the difference in sizes of the cathodes and, in the case of the embodiment of Figs. 1, 2 and 3 the fact that the caesium is produced in a side tube and must be driven into the tube container by heating or "flaming" the side tube.

Briefly described, the preferred method of sensitizing the cathode is as follows:

The tube is baked at about 400° C. to remove occluded gases from the bulb but this heating does not cause any chemical reaction in the caesium pellet. Oxygen is admitted into the container and the cathode is subjected to ionic bombardment in such a way that the first effect is to produce a heavy layer of silver oxide on the inner surface of the tubular cathode followed by a heating up of the silver tube and reduction of the layer of silver oxide. This cycle of oxidation and reduction is repeated after which the oxygen is pumped out of the container. This treatment leaves the inside surface of the cathode clean and slightly rough so that it has a uniform matte finish. A fresh charge of oxygen is admitted and by a succession of discharges of fixed amounts of electricity from condensers, the inner surface of the cathode is oxidized to an amount dependent upon the amount of caesium to be introduced. The caesium pellet is then inductively heated to effect a chemical reaction which produces caesium vapor. This vapor condenses on the inside walls of the side tube in Fig. 2 and on the inside walls of the container in Fig. 4. By heating the side tube in Fig. 2 with a flame the caesium is driven into and condenses principally on the inside walls of the container. The tube is then heated in a stream of hot air to a temperature of about 225° C. until the cathode has reached the desired sensitivity. Argon or other suitable gases may be admitted at low pressure to obtain the benefits of gas amplification.

Other materials may be used for the cathode and modified treating methods may be employed. Some of these materials and modified methods are described in the Glass patent supra. The ingredients of the caesium pellet are preferably those disclosed in this Glass patent.

While the examples of practice illustrated herein are photoelectric tubes, certain features of the invention are applicable to electron discharge devices generally. The feature of sealing the inner and outer walls together at such times as not to injure the cathode by overheating is applicable to any type of cathode which is injured by the temperatures necessary to seal the inner and outer walls together. Such cathodes may be thermionic, photoelectric, secondary emitting, or so-called cold cathodes, such as are used in gaseous discharge devices. The material of the cathode may be other than silver. Furthermore, the end of the outer wall member may be compressed to form a small circular aperture with an unflared inner wall member, in which case the outer electrode is preferably of a form which expands after it is inserted through the circular aperture. Still other embodiments of the invention will occur to those skilled in the electron discharge art in view of the specific examples herein disclosed.

What is claimed is:

1. An electron discharge device comprising an annular container having an outer cylindrical wall and an inner cylindrical wall having a conical portion forming a window at one end, said walls being sealed together at the respective ends of said walls, a tubular cathode within said container coaxial with said walls and supported from said outer wall but separated therefrom, an anode within said container and also inside said cathode, and lead-in wires sealed through said container wall and connected to said cathode and anode, respectively.

2. A method of manufacturing an electron discharge tube having an annular shaped container the outer wall element of which is substantially cylindrical, and having an electrode member shaped to conform approximately to said outer wall element, which member may be injured by heat, which method comprises forming for the inner wall of said container an element of generally cylindrical shape having one end flared to a diameter slightly less than the diameter of said outer cylindrical wall element, positioning said wall elements concentrically with the ends of one adjacent the respective ends of the other, sealing said elements together at the end remote from said flared portion by the application of heat, inserting said electrode member into said container through the space between said outer wall element and the outer end of said flared portion and securing it in position in said container so that it extends so close to the end thereof which has been sealed that it would have been injured by the heat applied in sealing had it then been so positioned, and subsequently sealing together said wall elements at the other end of said container.

3. A method of manufacturing in electron discharge device having an annular shaped container the walls of which are generally of cylindrical shape for at least a large portion of their length, and having a cathode member of approximately cylindrical shape, said member may be subject to injury by heat, which method comprises forming said walls separately and providing a taper at one end of at least one of said walls so that when said walls are assembled with their ends aligned the tapered extremity is slightly spaced from the adjacent end of the other wall, assembling said walls so that this spacing is effected, sealing together the other ends of the walls, inserting the cathode into the container through said space, and then applying heat to the wall ends which are spaced apart to effect softening and sealing.

4. A photoelectric tube comprising an outer cylindrical wall, an inner cylindrical wall having a conical portion at one end sealed to said outer wall and the other end also sealed to said outer wall, a tubular light sensitive cathode supported within said container and surrounding the major portion of said conical portion of said inner wall, an anode also supported within said container and lead-in wires sealed through said container wall and connected to said cathode and anode, respectively.

5. A photoelectric tube comprising an outer cylindrical wall, an inner cylindrical wall sealed at one end to said outer wall and having the other end also sealed to said outer wall and a central circumferentially corrugated portion, a tubular light sensitive cathode supported within said container surrounding said corrugated portion of said inner wall, an anode also supported within said container, and lead-in wires sealed through said container wall and connected to said cathode and anode, respectively.

6. A photoelectric tube comprising an outer cylindrical wall, an inner cylindrical wall having one end sealed to said outer wall and a flared portion at the other end also sealed to said outer

wall, a tubular light sensitive cathode within said container surrounding the inner wall near the end opposite the flared portion, a metallic capsule for light sensitive material connected between the ends of an open low resistance metallic ring, said ring forming part of the anode for said tube, and lead-in wires sealed through said container wall and connected to said cathode and anode, respectively.

7. An electron discharge device comprising an annular container having an outer cylindrical wall and an inner cylindrical wall having a central circumferentially corrugated portion, said walls being sealed together at the respective ends of said walls, a cathode conforming generally to the inside surface of said outer wall but separated therefrom positioned within said container and frictionally supported from said outer wall, an anode within said container, and lead-in wires sealed through said container wall and connected to said cathode and anode, respectively.

8. An electron discharge device comprising an annular container having an outer cylindrical wall and an inner cylindrical wall having a conical portion at one end, means closing the space between the respective ends of said walls with the inner wall within and coaxial with the outer wall, a tubular cathode within said container, means supporting said cathode from said outer wall in a position separated from said outer wall at a plurality of separated frictional points of relatively small area compared with the area of the cathode and surrounding the major portion of said conical portion of said inner wall.

9. An electron discharge device comprising an annular container having an outer cylindrical wall and an inner cylindrical wall coaxial with said outer wall and having a central circumferentially corrugated portion, a tubular cathode spring supported from said outer wall, an anode supported in operative relationship to said cathode, and lead-in wires connected to said cathode and anode, respectively.

10. A method of manufacturing an electron discharge device having an annular-shaped container the outer wall element of which is substantially cylindrical, and a tubular cathode which is injured by excessive heating, which method comprises forming for the inner wall an element of generally cylindrical shape having one end flared to a diameter slightly smaller than the diameter of the outer wall element, positioning the inner wall element within and coaxial with said outer wall element leaving a small opening between the outer wall and said flared portion of said inner wall, sealing the end of the inner wall element opposite said flared portion to the outer wall element, inserting the tubular cathode into said container through said opening, supporting an anode within said container during assembly, and sealing the inner and outer wall elements together adjacent said opening closing said opening.

11. A photoelectric tube comprising an outer cylindrical wall, an inner cylindrical wall having a conical portion at one end sealed to said outer wall, a flared portion at the other end also sealed to said outer wall and a central circumferential corrugated portion, a tubular light sensitive cathode supported within said container and surrounding the major portion of said conical portion of said inner wall, an anode also supported within said container, and lead-in wires sealed through said container wall and connected to said cathode and anode, respectively.

12. A photoelectric tube comprising an outer cylindrical wall, an inner cylindrical wall having a conical portion at one end sealed to said outer wall, a flared portion at the other end also sealed to said outer wall and a central circumferential corrugated portion, a tubular light sensitive cathode supported within said container and surrounding the major portion of said conical portion of said outer wall, an anode spring supported on said corrugations within said container, and lead-in wires sealed through said container wall and connected to said cathode and anode, respectively.

13. A photoelectric tube comprising an outer cylindrical wall, an inner cylindrical wall having a conical portion at one end sealed to said outer wall, a flared portion at the other end also sealed to said outer wall and a central circumferential corrugated portion, a tubular light sensitive cathode spring supported from the outer wall within said container, an anode also supported within said container, and lead-in wires sealed through said container wall and connected to said cathode and anode, respectively.

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