Sept. 28, 1954 G. W. BAKER 2,690,522

ELECTRON SPACE DISCHARGE DEVICE

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FIG. 1.

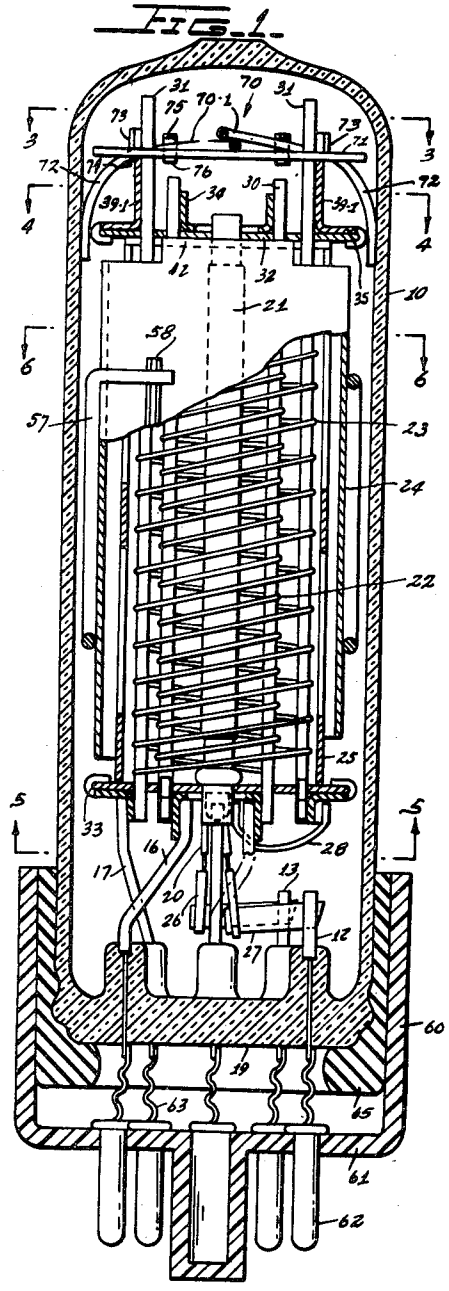
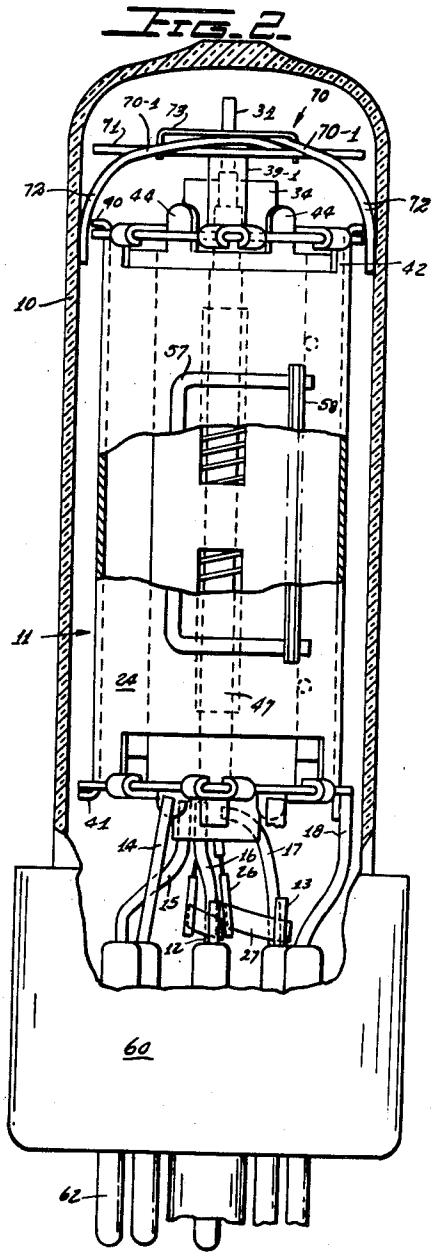


FIG. 2.



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FIG. 3.

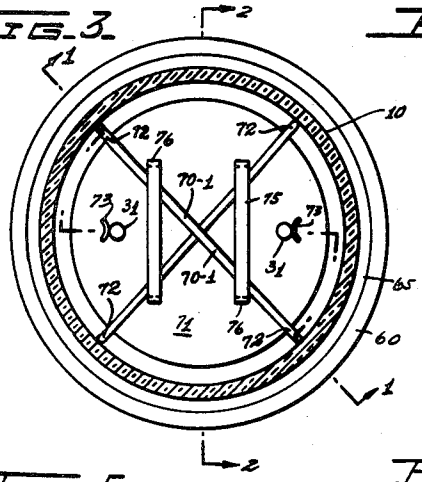


FIG. 4.

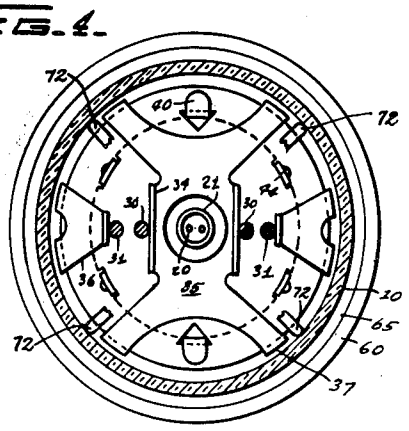


FIG. 5.

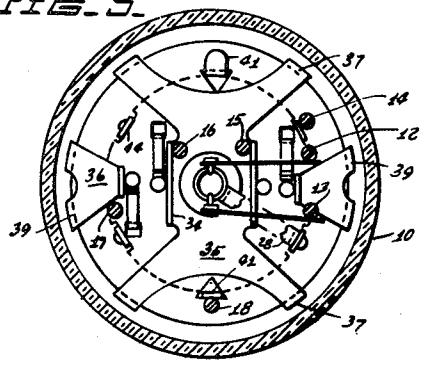
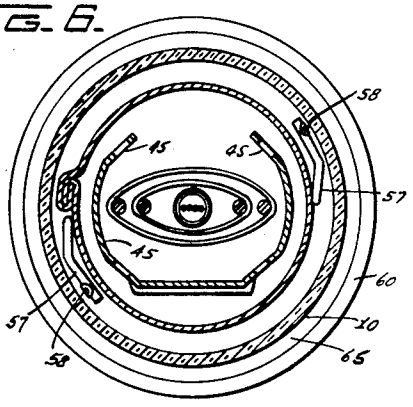


FIG. 6.



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FIG. 7

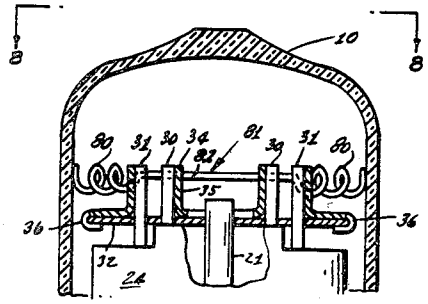


FIG. 8

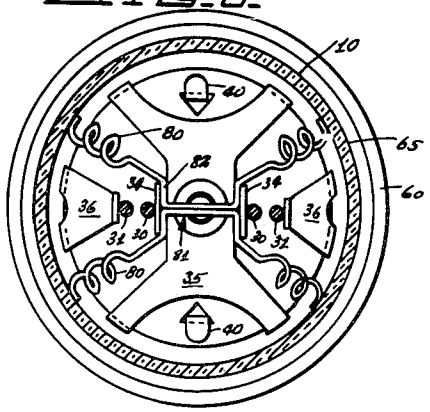
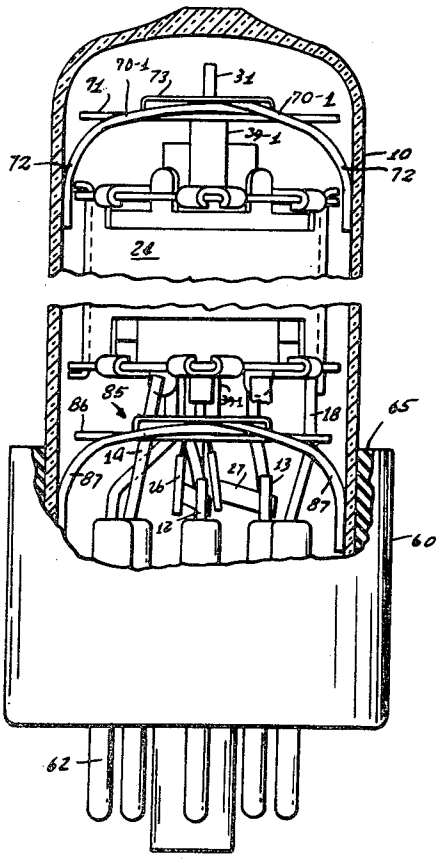


FIG. 9



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ELECTRON SPACE DISCHARGE DEVICE

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Application August 30, 1951, Serial No. 244,310

9 Claims. (Cl. 313—258)

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This invention relates to electron space discharge devices in which an electrode assembly comprising at least an anode and a cathode is enclosed in a hermetically sealed envelope.

Among the objects of the invention is an electron space discharge device of the foregoing type capable of withstanding severe and continuous, as well as abrupt, vibrations and mechanical shock without any impairment of the desired electrical characteristics of such device, and a method for producing the same.

Another object of the invention is a rugged electron space discharge device embodying novel features which make it possible to simplify the critical problems connected with their manufacture and a method for making it possible to manufacture such tubes on a mass production basis with a high degree of uniformity of their operating characteristics.

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 cross-sectional view of one form of a multi-electrode electron space discharge tube exemplifying the invention;

Fig. 2 is a vertical cross-sectional view of the same tube in a direction transverse to Fig. 1;

Fig. 3 is a cross-sectional view along line 3—3 of Fig. 1;

Fig. 4 is a cross-sectional view along line 4—4 of Fig. 1;

Fig. 5 is a cross-sectional view along line 5—5 of Fig. 1;

Fig. 6 is a cross-sectional view along line 6—6 of Fig. 1;

Fig. 7 is a vertical cross-sectional view of the upper portion of another form of tube exemplifying the invention;

Fig. 8 is a plan view along line 8—8 of Fig. 7; and

Fig. 9 is a partial vertical cross-sectional view of still another form of tube exemplifying the invention.

Although the principles of the invention are applicable to all types of electron tubes, their application will be explained herein in connection with a pentode-type tube which has a very wide use as a voltage gain and power amplifier, and is shown in Figs. 1 to 7.

The tube shown comprises an evacuated, generally elongated tubular envelope 10 of vitreous material, such as glass, which encloses an electrode assembly generally designated 11. The

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electrode assembly 11 comprises a plurality of electrodes which are connected to a plurality of leads 12, 13, 14, 15, 16, 17 and 18 hermetically sealed through an electrically insulated terminal end wall portion 19 of the envelope 10 to provide external circuit connections to the electrodes. The terminal end wall portion 19 is made in the form of a wafer-like stem of vitreous material sealed around portions of the lead conductors 12 to 18 which are shown arrayed thereon in a generally circular row. The wafer-like lead stem 19 extends in a direction transverse to the envelope 10 and is fused to its lower end border.

Referring to Figs. 1 and 2, the electrode assembly 11 comprises an indirectly heated cathode 21, a control grid 22, a screen grid 23 and anode 24, all extending longitudinally generally parallel to a common axis of the electrode assembly 11. An additional auxiliary electrode structure 25 is interposed across the electron path between the anode 24 and the screen grid 23.

The cathode 21 comprises a narrow tubular structure of metal, such as nickel, which encloses the heating filament 20 and is provided with an oxide coating which emits electrons when the cathode 21 is heated by the filament 20 to an elevated temperature.

The indirectly heated cathode has a heating filament 20 of a thin refractory metal, such as tungsten, and is shown to form a folded loop within the tubular cathode 21. The surface of the heating filament 20 is coated with an electrically insulating material in order to insulate the two filament loops from each other and from the metal cathode 21. Each of the terminal ends of the filament 20 are enclosed by a small metal sleeve 26, which in turn are attached, as by welding, to one end of metal connector elements 27. The other ends of the metal connector elements 27 are affixed, respectively, to electrode leads 12, 13 to provide external circuit connections to the filament 20.

The two grids 22, 23 are made of very fine refractory metal wire, the inner grid being wound as a helix on and secured to two inner side rods or grid posts 30, and the outer grid 23 being similarly wound and supported on two outer side rods or grid posts 31.

The grid posts 30, 31 as well as the cathode 21, anode 24 and auxiliary electrode 25 are held in their operative position by two similar generally flat sheet-like insulating spacer elements 32, 33, made of a material having a high dielectric constant, such as mica. The two sheet-like in-

sulating spacers 32, 33 are provided with apertures or openings engaged by junction or supporting ends of the cathode 21, the grid posts and of the other electrodes which are joined by the spacers into a self-supporting electrode assembly.

In order to prevent microphonics and retain the desired operating characteristics of such tube, it is essential that there be no movement between any of the elements of the electrode assembly and that the individual electrodes retain their proper relative spacing even if the tube is exposed to a vibratory movement. Heretofore, the required rigidity between the grids and the insulating spacers was provided by push-fitting the grid posts into undersized openings in the insulating spacers. However, this was found to be insufficient because extended and/or severe vibrations to which the tube is subjected in some of its applications would enlarge the openings in the insulating spacers and result in loosening of the grids with a consequent disturbance in the operating characteristics and microphonic action.

These difficulties are overcome by combining the sheet-like insulating spacer—having a spacer opening engaged by a junction portion of an electrode which is to be prevented from lateral movement within the spacer opening—with a relatively stiff metallic bracing member extending adjacent to the spacer, with one portion of the bracing member affixed to the electrode junction portion and another portion of the bracing member secured to the insulating spacer so as to prevent lateral movement of the so-braced electrode within its spacer opening.

The so-braced electrode is further braced by affixing the inner ends of at least one relatively stiff stem lead to the bracing member or to the electrode junction portion to which the bracing member is affixed.

In the particular tube shown in Figs. 1 to 5, both the control grid 22 and the screen grid 23 have to be maintained in their critically spaced positions on the two spacers 32, 33, and they are held braced.

Referring to Figs. 1 to 5, each insulating spacer 32, 33 has attached thereto three stiff bracing members 35, 36 of suitable sheet metal, such as nickel or stainless steel.

The center bracing member 35—which braces the control grid 22—comprises a flat sheet-like structure abutting the surface of the respective insulating spacers 32, 33. The bracing member 35 has a plurality of arm extensions 37 projecting beyond the periphery of the insulating spacer 32, 33. Each brace arm extension 37 is clamped around the outer edge of the insulating spacer to form a good substantially rigid connection therewith.

The center portion of each bracing member 35 has two oppositely facing stiff wings or flanges 34 held in a plane parallel to the common axis of the tube and positioned so that the two opposite flanges 34 engage the two opposite junction projections of the control grid posts 30. The control grid posts 30 are affixed to the stiff flanges 34 as by welding. The center portion of the bracing member 35 is also provided with an opening 38 to provide clearance for the support connection to the filamentary cathode 21. As can be seen from the above detailed construction, the bracing of the control grid 22 against lateral movement is provided by two stiff control grid bracing members 35 to which the control grid posts 30 are affixed and which in turn are securely clamped to their respective insulating spacer 32, 33. The control grid bracing members 35 also act to absorb any mechanical stresses tending to buckle the insulating spacers 32, 33.

The screen grid 23 is generally similarly braced at its opposite ends by two screen grid bracing members 36 (Figs. 1, 3, 5). Each bracing member 36 comprises a stiff flat sheet-like V-shaped structure abutting the respective insulating spacers 32, 33 and positioned between the brace arm extensions 37 of the control grid bracing member 35. Each bracing member 36 is V-shaped and has two arms 39 which extend beyond the periphery of the respective insulating spacer 32, 33 and are clamped around its outer edge and substantially rigidly attached thereto. The center facing portion of each screen grid bracing member 36 has a stiff wing or flange 39—1 held in a plane parallel to the common axis and engaging the outwardly projecting junction portions of the two screen grid posts 31 respectively, to which the flange 39—1 is affixed as by welding. Thus the rigid positioning of the screen grid 23 is provided by both pairs of stiff bracing members 36 to which the screen grid posts 31 are affixed and which in turn are securely clamped to their respective insulating spacers 32, 33.

It should be noted that the two sets of grid bracing members 35, 36 extend adjacent the outwardly facing surfaces of the insulating spacers 32, 33 for bracing the junction portions of the control grid 22 and screen grid 23.

The bottom grid post junction portions of the two grids 22, 23 are additionally braced relatively to the bottom insulating spacer 33 by stiff connections in the form of electrode leads 15, 16 and 17 which are in turn secured to the rigid envelope 10.

As shown in Figs. 1 and 5, the flanges of the lower control grid bracing member 35 has affixed thereto two stiff envelope leads 15, 16, which are in turn rigidly secured to the end wall portion 19 of the envelope 10. The screen grid bracing members 36 to which the junction portions of the screen grid posts 31 are secured, are additionally braced by a stiff envelope lead 17 which is affixed thereto, as by welding.

This construction secures the grid structures through a stiff stem lead to the rigid stem 19 of the tube, which in turn is a part of the rigid envelope 10.

The anode 24 is made in the form of a cylindrical tubular sheet structure of thin metal, such as nickel. Each of the opposite generally circular boundary edges of the anode 24 have anode junction portions in the form of two spaced sheet ears 40, 41, interlockingly engaging and interfitting with two spaced retainer recesses in the insulating spacers 32, 33, so as to secure the two insulating spacers to the upper and lower ends, respectively, of the tubular anode 24 and join them into a self-supporting assembly.

The boundary edges of the anode 24 are provided with intermediate shoulder portions 42 against which the two spacers 32, 33 abut when they are joined to the anode 24, to provide gap spacers between the major portion of the circular boundary edges of the anode 24 and the facing portions of the spacers 32, 33. This construction permits the escape of any gases generated during the degassing operation to which the completed tube is subjected.

External circuit connection to the anode 24 is provided by electrode lead 18 which is affixed to a junction sheet ear 41 thereof.

After securing the insulating spacers 32, 33 to

the anode 24, the anode junction ears 40, 41 may be bent in an outward direction to provide a firm mechanical interconnection therebetween.

In the form of tube shown in Figs. 1 to 5, an auxiliary or shield electrode 25 is interposed between the anode 24 and the screen grid 23 and utilized as a suppressor electrode to shield against secondary emission from the anode 24 and define the effective electron beam.

The auxiliary electrode 25 is shown formed of two oppositely facing inter-connected curved sheet metal structures 45. Each curved shield electrode structure 45 has two generally centrally positioned elongated openings 47 which permit access to and viewing of the grids 22, 23 and facilitates their alignment in their proper operative positions. Each of the opposite curved boundary edges of each shield electrode structure 45 have sheet-electrode junction portions in the form of two sheet ears 44.

The shield-electrode junction sheet ears 44 interlockingly engage with spaced retainer recesses 48 in the insulating spacers 32, 33 and are held therein. After the insulating spacers 32, 33 are joined with the auxiliary electrode 25 into a self-supporting assembly, some of the junction sheet ears 44 may be bent in an outward direction to provide a better mechanical interconnection therebetween.

The opposite ends or junction portions of the tubular cathode 21 are held by a press fit in their properly spaced positions within seating openings of the insulating sheet spacers 32, 33. The tubular cathode 21 is internally electrically connected to the shield electrode 25 at a junction portion 44 thereof by a metal link 28 whose opposite ends are affixed to both a junction portion of the cathode 21 and a junction sheet ear 44 of the shield electrode 25, respectively. External circuit connection to both the cathode 21 and the shield electrode 25 is provided by electrode lead 14 which is affixed to another junction sheet ear 44 of the shield electrode 25.

Referring to Figs. 1 to 5, a getter structure 57, in the form of two rectangular members, is attached to opposite outwardly-facing sheet walls of the anode 24 which are spaced at a distance from the insulating spacers 32, 33 and extends generally parallel to the common axis of the tube. A getter body 58 is affixed to a portion of the getter structure 57. The anode 24 constitutes a barrier which confines the evaporated getter material 58 to the region of the envelope 10 facing away from the insulating spacers 32, 33 so as to prevent getter vapor from materially reducing the surface leakage resistance of the insulating spacers 32, 33.

Heretofore, the method used to procure a ruggedized tube capable of withstanding severe and continuous, as well as abrupt, vibrations and mechanical shock was by providing the tube with an extremely rigid electrode assembly. This was generally found to be sufficient to withstand most normal shock and vibration. However, extreme impact stresses would tend to break the vitreous envelope and/or portions of the electrode assembly.

According to one phase of the invention, the tube is provided with a relatively flexibly coupled substantially rigid base 60 which will permit limited movement between the base 60 and the envelope 10 of the tube and thereby result in a tube capable of absorbing an enormous amount of impact stress without fracturing.

One phase of the invention concerns itself with

providing an electron space discharge device comprising a hermetically sealed envelope 10 enclosing a plurality of electrodes 11, which envelope 11 is attached to a substantially rigid base 60 by a relatively pliable material 65 which is arranged so that when the device is subjected to severe and continuous, as well as abrupt, vibrations and mechanical shock, such relatively pliable material will absorb a substantial amount of such shock, thereby preventing any impairment of the desired electrical characteristics of such device.

Referring to Figs. 1 and 2, in the specific form shown, the base 60 comprises a thin generally circular cup-like structure which encloses a substantial part of the lower portion of the envelope 10. The base 60 is generally composed of an electrically insulating material, such as a phenolic condensation product. The bottom portion or end 61 of the base has affixed therein a plurality of rigid metal connector pins 62 extending therefrom in a plane parallel to the common axis of the tube and arrayed thereon in a generally circular row. A plurality of flexible leads 62 which will permit movement of the envelope 10 relatively to the base 60 are loosely connected between the rigid connector pins 62 and each stem lead 12 to 18, respectively, held fixed in the end wall portion 19 of the tube. The rigid connector pins 62 serve to provide external circuit connections through the flexible leads 62 and the stem leads 12 to 18 to the various electrodes of the electrode assembly 11.

The space separating the inner surface of the rim of the base 60 and the corresponding facing outer surface of the envelope 10 contains elastomer material 65 which forms a bond with both the base 60 and with the envelope 10. The cement forms a sufficiently stiff bond that permits limited vibration suppressing movement between the envelope and the base when subjected to disturbing vibrations—but which resist any substantial movement therebetween. Accordingly, a substantial amount of any impact or vibration stress directed against the tube will be absorbed by the pliable junction layer 65 thus permitting the tube to withstand large impacts and vibrations without fracture. On the other hand, the bond or junction layer between the base and the envelope is made sufficiently stiff so that the tube with its base may be readily removed as a whole from the base socket by gripping the envelope and pulling it out of the socket.

It is of advantage to combine a foaming agent with the bonding material used for forming the pliable joint between the base and the envelope so that when curing the bonding material gas is developed in the bonding layer causing the bonding layer to expand and thus greatly increase the bond between the junction layer with the base and envelope, respectively, while at the same time increasing the pliability of the junction layer and also forming a moisture resistant seal which prevents entry of moisture and corrosion of the metal elements within the base.

Any of the known rubber, rubber-like or elastomer materials which may be expanded into foam rubber body in the curing process or otherwise may be used as the bonding material for providing the pliable junction layer between the envelope and the base in accordance with the invention.

In this treatment the layer of bonding material is expanded by its foaming agent, thereby increasing its union with the coated surfaces of

the base and envelope respectively and also increasing or giving the junction layer interposed therebetween the desired pliability.

Very good results are obtained by using as a bonding material standard commercially available grades of silicon rubber paste which, in curing, solidifies into an expanded stable rubber-like body, such as the commercially available silicon rubber paste known as Dow-Corning Silastic No. 110. The following procedure is used for forming with such silicon rubber paste a pliable junction between the base **60** and the tube envelope **10**. A thin stratum or film of the silicon rubber paste is applied to the facing surfaces of the base **60** and the envelope **10** which are to be joined. The thin surface coating is thereafter partially cured by heating for about 15 minutes at a temperature of about 165° C. while exposed to air, resulting in surface coating films which are free from foam or gas spaces and which adheres firmly to the coated surfaces.

In general, a thin coating of the bonding material is first applied to the facing surfaces of the base and the envelope which are to be joined to each other. The coating layer or stratum so applied is partially cured, for instance, by heating in air so that it adheres tightly to the underlying surfaces of the base and the envelope, respectively.

After the partial curing of the base and envelope coatings, the loose flexible leads **63** are connected, as by soldering, between the connector pin **62** of the base and the stem leads **12** to **18** of the envelope.

The envelope is then positioned within the base **60** and held therein in properly spaced position as by a suitable jig. The gap space between the film coated base and the firm coated envelope portions is then filled with the required quantity of the bonding material including the foaming agent out of which the pliable joint is to be formed. Thereafter, the base with the envelope so joined to each other are subjected to a treatment in which the bonding material placed therebetween is cured at an elevated temperature, for instance, thereby causing the bonding layer to be firmly united with the coated surfaces of the base **60** and the envelope **10** respectively.

After completing the partial curing, the loose flexible leads **63** are connected between the connector pins **62** of the base and the stem leads **12** to **18** of the envelope as by soldering.

With the so-coated envelope portion held in its position within the so-coated base **60**, the gap spacing therebetween is filled with the silicon rubber paste to form the junction layer **65**.

The so completed assembly of envelope **10** and base **60**—with its layer **65** of silicon rubber paste filling the gap between the film coated surfaces of the base and envelope respectively—is then subjected to a curing treatment at 140° C. for about two to four hours, within a suitable furnace, for instance. In this curing treatment, the silicon rubber paste generates gases which cause expansion of the bonding layer **65** formed thereof, thereby providing a tight union and anchoring junction between the expanded junction layer **65** and the coated surfaces of the base and envelope, respectively. In addition, the cured silicon rubber layer **65** forms a foam-like rubber structure which constitutes a seal against entry of moisture or fungi foreign matter into its interior and into the interior of the base sealed thereby.

A tube envelope so joined to the base will permit limited vibration suppressing movement of the envelope within the base while providing a firm connection therebetween which permits withdrawal of the tube from the socket by the application of pulling forces to the upper portion of the envelope projecting above the base. Such tube will also meet the standard accepted torque test in which the base is held fixed against rotation and a torque of 20 inch-pounds is applied to the envelope without disturbing or breaking the union between the base and the envelope.

The curing of the pliable material **65** with its foaming agent mixture provides an effective moisture-resistant bond with the two films. The mixture expands during curing to press tightly against the facing surfaces of the envelope and the base and provides a sealed secure bond between the base **60** and the envelope **10**. This tight bond permits the envelope **10**, under stress, limited twisting or bending within the base **60** whereby the pliable material **65** absorbs a substantial part of the stresses existed against the tube and prevents fracturing of the envelope **10** and/or the electrode assembly **11**.

The end or bottom portion **61** of the base is kept free of the pliable material **65** in order to prevent electrical leakage between the various metal elements. The excess cured pliable material **65** that has expanded beyond the boundary edges of the base **60** is trimmed off.

By way of example, without thereby limiting the scope of the invention, in order to enable those skilled in the art to readily practice the invention, there are given below data for a tube exemplifying the invention:

The outside diameter of the envelope **10** is about $1\frac{1}{16}''$. The outside diameter of the molded phenolic base **60** is about $1\frac{5}{16}''$. The space separating the facing surfaces of the molded phenolic base **60** and the envelope **10** which is filled with the pliable junction layer material **65** is about $\frac{1}{16}''$.

The height of the molded phenolic base **60** is about $\frac{13}{16}''$. About $\frac{1}{2}''$ of the lower portion of the envelope **10** is surrounded by the molded phenolic base **60**.

The pliable junction layer material **65** is formed in the manner described in pages 12, 13 and 14 of the specification.

There are many applications requiring electron tubes capable of withstanding extremely high impact shocks, sometimes in the order of 200 to 2000 g for the duration of about $\frac{1}{100}$ millisecond to several milliseconds, where g is the gravity force of 981 gram×cm./sec.^{2}.

According to one phase of the invention, electron space discharge devices are rendered capable of withstanding such great mechanical impact shocks without impairment of their desired electrical characteristics by flexible mounting of the electrode assembly within the envelope and by providing spring structures affixed to its electrode assembly for absorbing at least the initial shock of such impact.

According to this phase of the invention the electron space discharge device, which is to be made rugged enough to withstand great mechanical impact shocks, is provided with one or more spring structures affixed thereto and having deformable spring elements engaging spaced inner surface portions of the envelope arranged to be deformed by movement of said assembly toward facing portions of the envelope for absorbing at least the initial shock of an im-

pact and for returning the assembly to its normal position.

Referring to Figs. 1 to 6, a spring structure 70 is shown affixed to an upper portion of the electrode assembly 11. In the specific form shown, the spring structure 70 comprises two crossed deformable spring members 70–1 held affixed to an additional insulating spacer 71 which is positioned above the upper insulating spacer 32. The two crossed spring members have four peripherially displaced spring arms 71 with substantially equally spaced bent end portions 72 extending into engagement with the facing inner wall surface of the envelope 10. The bent end portions 72 of the four deformable spring elements 70–1 which engage inner spaced facing surface portions of the envelope 11 extend in a direction generally parallel to the axis of the envelope.

The peripheral edges of the upper and lower insulating spacers 32, 33 are spaced by a small distance from the inner facing surface portions of the envelope 10 thereby permitting the electrode assembly 11 to move relative to the envelope 10.

The electrode leads 12 to 18 which provide external circuit connections to the various electrodes of the electrode assembly 11 are made flexible in a lateral direction but inflexible in an axial direction. The foregoing construction permits the electrode assembly 11 to move in a lateral direction relative to the envelope 10 but will not permit any axial movement of such assembly 11.

When the tube is subjected to an impact shock, the electrode assembly 11 will bend or deflect or laterally move within the envelope 10 thereby deforming and biasing the spring elements 72 which engage inner facing surface portions of the envelope 10. The spring elements 72 are designed to exhibit non-linear deformation characteristics so that after a predetermined initial deformation of the assembly 11 relative to the envelope 10, all further movement tending to increase the deformation of the spring elements 72 will be prevented.

Due to the non-linear deformation characteristics exhibited by the spring elements 72, the peripheral edges of the insulating spacers 32, 33 will not make contact engagement with the inner facing surface portions of the envelope 10 no matter how great are the impact shocks to which the tube is subjected.

The bent in arm ends 72 of the four spring arms 70–1 of the spring structure 70 is so designed that—when the electrode assembly is accelerated by a shock impact to move against a facing surface portion of the envelope 10—the initial movement of the electrode assembly toward the facing envelope portion will cause the bent arm ends 72 to be further bent and deformed. This brings a greater length of each spring end arm 72 in engagement with the facing envelope structure thereby effectively shortening the so bent spring arms 70–1 and stiffening them against further deformation. As a result further movement of the electrode assembly toward the facing envelope wall is taken up by a shorter length of the correspondingly bent spring arms 70–1 which extend to a greater extent in a direction substantially perpendicular to the facing envelope wall thereby rapidly increasing the resistance of the respective spring arms 70–1 to undergo further deformation. This process continues until the stiffness of the so bent spring arms 70–1 has reached a level at which further movement of the electrode assembly toward the envelope is stopped with a gradual rigidifying cushioning action. The cushioning spring structure is so designed that this stopping action of the spring arms 72 becomes effective in stopping the movement of the electrode assembly before any of the other essential parts of the electrode assembly come into direct engagement with the facing envelope wall portions toward which they move.

In other words—when a tube having such non-linear spring elements interposed between the relatively stiff electrodes assembly and the relatively rigid envelope is subjected to an energy impact—the electrode assembly 11 will in its impact movement toward a facing portion of the envelope cause initial deformation of the interposed spring elements which will absorb part of the impact energy, with the spring elements stopping further impact movement of the electrode assembly beyond certain initial deformation of the spring elements as the impact forces are passing their peak.

The relatively rugged electrode assembly 11 shown is carried as a self-supporting relatively rugged unit within the envelope by a plurality of flexible leads 12 to 18 extending from the electrodes of the assembly and having portions sealed through a wall portion of the envelope.

The sealed through flexible leads 12 to 18 which extend from the electrode assembly 11 to the terminal wall portion of the envelope are so arranged as to permit limited movement of the electrode assembly 11 toward facing portions of the envelope 10 before essential parts of the electrode assembly 11 come into a direct contact with the envelope 10. The non-linear spring elements are combined and connected to the structural part of the electrode assembly which tends to move with the greatest amplitude toward the envelope 10.

The cushioning spring structure or structures act as shock absorbers to absorb the greater portion of the impact and prevent the impact forces from acting on the electrode assembly and impairing the desired electrical characteristics of the tube.

The conventional connections which affix the electrode assembly 11 to the end wall portion 19 of the tube are generally in the form of ductile metal leads 12 to 18. Such metal connections will normally permit the electrode assembly 11 to deflect relatively to the envelope 10 provided that the electrode assembly was free to move in a lateral direction. In the conventional construction, the diameter of the insulating spacers 32, 33 is chosen so that its peripheral edge will engage the inner surface of the envelope 10 and thereby prevents movement of the electrode assembly 11 relatively to the envelope 10 of the tube.

In the tube of the invention, the diameter of the insulating spacers 32, 33 is chosen so that its peripheral edge and the corresponding facing inner surface of the envelope are spacially separated to permit the electrode assembly 11 to deflect or bend relatively to the envelope 10. The proper operative position of the electrode assembly 11 within the envelope 10 is maintained by the action of the spring structure 70.

Referring to Figs. 1 to 3, in the specific form shown, the electron space discharge device of the invention is shown with a spring structure 70 affixed to an upper portion thereof. The spring structure 70 comprises an additional insulating

spacer 71 having attached thereto and extending therefrom a plurality of spring steel elements 70–1 having bent ends 72 which engage substantially equally spaced inner surface portions of the envelope 10.

In the form shown, the spring structure 70 has been assembled on and attached to a third insulating spacer 71 mounted on the screen grid posts 31 extending above the upper insulating spacer 31. The downward facing surface of the spring assembly insulating spacer 71 is in contact engagement with the upper boundary edge 74 of the screen grid bracing strip flange 33–1. The additional insulating spacer 71 is maintained in its operative position by two small holding elements 73 secured to the portion of the screen grid posts 31 extending above the upward facing surface of the spacer 71 and in contact engagement therewith.

The spring steel elements 70–1 are mounted on the upward facing surface of the additional insulating spacers 71 and consist of two crossed spring steel metal rods having opposite end portions 72 that are bent in a downward direction toward the end wall portion 19 of the tube and engage the inner surface of the envelope 10. The crossed center portions of the spring elements 70–1 extend adjacent to the outer surface of the insulating spacer 71 and are secured to each other at the crossed portion, as by welding. They are maintained in their operative position by two spaced substantially rigid generally parallel holding members 75 having axially bent junction end portions 76 which are interlockingly engaged in recesses in the additional insulating spacer 71.

Referring to Fig. 3, the two holding members 75 abut the outer surface, respectively, of each of the two crossed spring steel members 70–1 thus serving to hold and maintain them in their position adjacent to the outer surface of the additional insulating spacer 71 when the bent end portions 72 of the spring steel members 70–1 are flexed or bent by lateral movement of the electrode assembly 11 within the envelope 10.

Then bent end arms 72 of the spring steel members 70–1 are arranged so that they will be flexed or biased when the electrode assembly 11 is placed within the envelope 10 so as to firmly engage the inner surface of the envelope 10 at generally equally spaced portions thereof and prevent any movement of the electrode assembly 11 from its generally centrally-located position within the envelope 10 under normal operating conditions. When the tube is subjected to an impact shock, the electrode assembly 11 will move in a lateral direction within the envelope 10 thereby further biasing or deforming some of the bent end portions 72 of the spring steel members 70–1. The furthest position of the electrode assembly 11 from its normal generally center location within the envelope 10 will be reached when the compressive forces exerted by the spring steel members 70–1 become equivalent to the acting impact forces. When the impact shock terminates, the stored potential energy of the flexed or biased springs 70–1 will restore the electrode assembly 11 to its normal generally centrally-located position within the envelope 10.

The spring steel members 70–1 are designed so as to exhibit non-linear deformation characteristics whereby the springs will increase in stiffness as the lateral deflection of the electrode assembly 11 increases and will prevent any further lateral movement of the electrode assembly 11 before any of the other essential parts of the electrode assembly 11 come into direct engagement with the facing envelope wall portions toward which they move.

The bent end arms 72 of the spring members 70–1 engage the inner surface of the envelope 10 at generally equally spaced portions thereof so as to create a balanced spring system in which each bent end arm 72 is generally equally biased thereby assuring the proper centrally-located position of the electrode assembly 11 within the envelope 10.

The principles of the present invention are applicable notwithstanding the particular kind of spring elements used or the means by which such spring elements are mounted on the electrode assembly 11.

Figs. 7 and 8 show the upper part of another form of tube construction exemplifying the principles of the invention. All of the elements of the electrode assembly of the tube of Figs. 7 and 8 are identical with those of the tube shown in Figs. 1 to 6. However, the tube of Figs. 7 and 8 has—in lieu of the straight spring steel members 70–1 affixed to an additional insulating spacer 71—a plurality of inter-connected coiled spring steel members 80 extending generally parallel to the upper insulating spacer 32 and affixed, respectively, to the flange portions 34 of the control grid bracing member 35.

In the specific form shown, the control grid bracing member 35 is made use of in order to eliminate the need for an additional insulating spacer. Each coiled spring member 80 forms a part of a generally cross-shaped metal structure 81 which maintains the coiled spring members 80 in their proper operative position in which they engage generally equally spaced inner surface portions of the envelope 10. Although the coiled spring steel members 80 are shown, for simplicity, exaggerated with uniformly spaced turns, the turns are actually arranged in the following manner: Only the outer turns will have wide spacing. The more inward turns will be more closely spaced so that under impact the coil turns will come into engagement after predetermined initial deformation of the electrode assembly 11 relatively to the envelope 10 and stop further deformation.

The generally cross-shaped metal structure 81 comprises two generally V-shaped spring metal rods 82 extending generally parallel to the upper insulating spacer 32 having opposite ends, respectively, formed into coil springs 80. The center portions of each spring metal rod 82 are affixed to each other and to inner side portions of the two rigid flanges 34 of the control grid bracing member 35, for instance, as by welding. The cross-shaped metal structure 81 holding the coiled spring members 80 in their operative position in which they engage spaced inner surface portions of the envelope 10 is spaced by a short distance from the outer surface of the upper insulating spacer 32.

The coiled spring members 80 are arranged so that they will be biased or compressed when the electrode assembly 11 is placed within the envelope 10 so as to firmly engage the inner surface of the envelope 10 and prevent any movement of the electrode assembly 11 from its generally centrally-located position within the envelope 10 under normal operating conditions. The coiled spring members 80 engage the inner surface of the envelope 10 at generally equally spaced portions thereof so as to create a balanced spring system in which each spring element 80 is generally equally biased thereby assuring the proper

centrally-located position of the electrode assembly 11 within the envelope 10.

The coiled spring members 80 will allow lateral movement of the electrode assembly 11 relatively to the envelope 10 when the tube is subjected to an impact shock so as to cause the springs to compress and elastically store or absorb the energy imparted to the tube by such impact thereby preventing breakage of essential parts of such tube. The stored potential energy of the spring members 80 will restore the electrode assembly 11 to its proper position within the envelope 10 when the impact has terminated.

Fig. 9 shows still another form of tube construction exemplifying the principles of the invention. All of the elements of the electrode assembly of the tube of Fig. 9 are identical with those of the tube shown in Figs. 1 to 6. However, the tube of Fig. 9 has—in addition to the single spring structure 70 attached to the upper portion of the tube of Figs. 1 to 6—an additional spring structure 85, similar in form to the spring structure 70 of Figs. 1 to 6, affixed to a bottom portion of the electrode assembly 11.

Referring to Fig. 9, in the specific form shown, the additional spring structure 85 comprises a fourth insulating spacer 86 having atttached thereto and extending therefrom a plurality of spring steel members 87 whose bent ends engage generally equally spaced inner surface portions of the envelope 10 in a manner similar to the spring steel members 70–1 of Figs. 1 to 6. The spring structure 85 is maintained in its operative position affixed to a lower portion of the electrode assembly 11 in a manner similar to the way in which the spring structure 70 of Figs. 1 to 6 is affixed to an upper portion of the electrode assembly 11. The inner surface of the fourth insulating spacer 86 engages boundary edges of the flange portions 39–1 of the two screen grid bracing members 36. The spacer 36 is prevented from axial movement by two small holding members, not shown, which abut the outer surface thereof and are affixed to the portion of the screen grid posts 31 which extend below the spacer 86 in a manner similar to the holding members 73 shown in Figs. 1 to 6. The fourth spacer 86 has a plurality of openings for the electrode leads 12 to 18 which are connected to junction portions of the various electrodes and through the end wall portion 19 of the tube.

In the specific form shown, the electrode leads 12 to 18—anchoring the electrode assembly 11 to the end wall portion 19 of the tube—permit lateral movement of the entire electrode assembly 11 within the envelope 10 but no axial movement. Such a construction will permit both spring structures 70, 85 to absorb all impact shock forces tending to break or bend the electrode assembly 11 within the envelope 10 thereby materially reducing tube fracture in those applications where the tubes are subjected to such impact shocks. Since there are no springs absorbing forces in an axial direction, the electrode leads 12 to 18 must be sufficiently rigid in such axial direction so as to maintain the electrode assembly 11 in its proper position away from upper and lower inner surface portions of the envelope 10.

The biasing of both spring structures 70, 85 when the electrode assembly 11 is pushed within the envelope 10 will maintain the electrode assembly in its generally centrally-located operative position. The spring steel members 70–1, 87 are provided with non-linear deformation characteristics so that an increase in lateral movement of the electrode assembly will result in an increase in stiffness of the spring members 70–1, 85. The spring members 70–1, 85 are arranged so that the electrode assembly 11 will be unable to move further in a lateral direction before the peripheral edges of either of the insulating spacers 32, 33 or any of the other parts of the electrode assembly 11 makes contact engagement with inner facing portions of the envelope 10. Accordingly, no essential part of the electrode assembly 11 will ever touch or engage the envelope 10.

It will be apparent to those skilled in the art that the novel principles of the invention disclosed herein in connection with specific exemplifications thereof will suggest various other modifications and applications of the same. It is accordingly desired that in construing the breadth of the appended claims they shall not be limited to the specific exemplification of the invention described herein.

I claim:

1. In an electron space discharge device: an electrode assembly including at least two different electrodes held insulated from each other in predetermined relative spacing, an envelope enclosing said assembly and being spacially separated therefrom, said electrodes having each flexible leads sealed through a sealing wall portion of said envelope to provide external connections to said different electrodes, said leads permitting movement of said assembly from a normal position toward facing wall portions of said envelope but substantially preventing movement of said assembly toward and away from said sealing wall portion, said assembly having deformable metallic spring elements with non-linear deformation characteristics extending from the assembly toward said envelope and arranged to be deformed by impact movement of said assembly toward facing wall portions of said envelope for absorbing at least the initial shock of a movement-inducing impact and for returning said assembly to its normal position, said non-linear deformation characteristics of said spring elements being effective after a predetermined initial deformation by said impact movement to prevent further impact movement of said electrode assembly relatively to said facing wall portions tending to increase said deformation beyond said initial deformation.

2. In a space discharge device as claimed in claim 1, said spring elements extending from an outer portion of said assembly opposite to the inner portion of the assembly joined by said leads to said sealing wall portion.

3. In a space discharge device as claimed in claim 2, said assembly having two sheet-like insulating spacer members engaging opposite junction portions of said different electrodes for holding them in their spaced relation and having an additional insulating sheet member, said spring elements being held in their operative position by said additional sheet member and having peripherally displaced ends engaging peripherally spaced inner wall portions of said envelope.

4. In a space discharge device as claimed in claim 3, said assembly having two sheet-like insulating spacer members engaging opposite junction portions of said different electrodes for holding them in their spaced relation and having an additional insulating sheet member, said spring elements being held in their operative

position by said additional sheet member and having peripherally displaced ends engaging peripherally spaced inner wall portions of said envelope, the ends of said spring elements engaging said facing wall portion being bent in a direction toward said sealing wall portion.

5. In a space discharge device as claimed in claim 1, said assembly having two sheet-like insulating spacer members engaging opposite junction portions of said different electrodes for holding them in their spaced relation and having an additional insulating sheet member, said spring elements being held in their operative position by said additional sheet member and having peripherally displaced ends engaging peripherally spaced inner wall portions of said envelope.

6. In a space discharge device as claimed in claim 5, the ends of said spring elements engaging said facing wall portion being bent in a direction toward said sealing wall portion.

7. In a space discharge device as claimed in claim 1, said spring elements extending from an outer portion of said assembly opposite to the inner portion of the assembly joined by said leads to said sealing wall portion, the ends of said spring elements engaging said facing wall portion being bent in a direction toward said sealing wall portion.

8. In a space discharge device as claimed in claim 1, said spring elements extending from an outer portion of said assembly opposite to the inner portion of the assembly joined by said leads to said sealing wall portion, an inward portion of each of said elements extending in a direction generally transverse to the axis of said envelope and the end portions of said elements being peripherally displaced and extending generally parallel to the inner wall surface of said envelope towards said sealing wall portion.

9. In a space discharge device as claimed in claim 1, said spring elements extending from an outer portion of said assembly opposite to the inner portion of the assembly joined by said leads to said sealing wall portion, said spring elements having peripherally displaced coiled end portions engaging said facing wall portions.

References Cited in the file of this patent

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Number	Country	Date
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