

Oct. 23, 1951

H. R. JACOBUS, JR.
ELECTRODE AND ENVELOPE ASSEMBLY FOR MULTIELECTRODE
SPACE DISCHARGE DEVICES

2,572,031

Filed Jan. 26, 1949

2 SHEETS—SHEET 1

FIG. 1

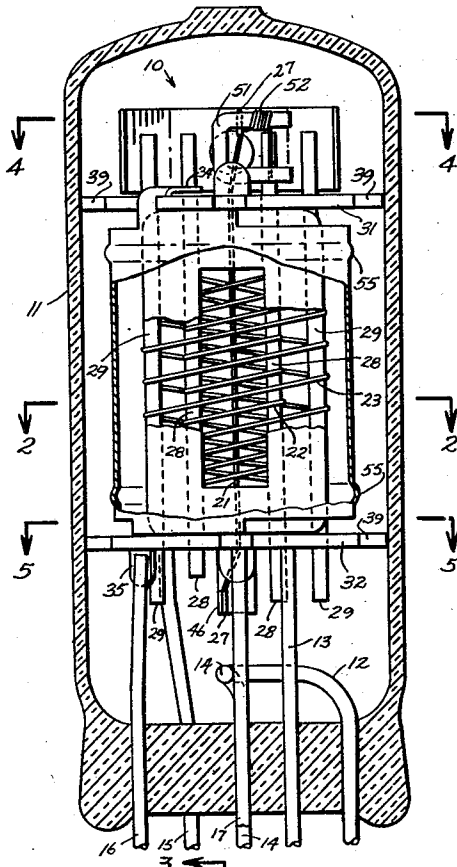


FIG. 3

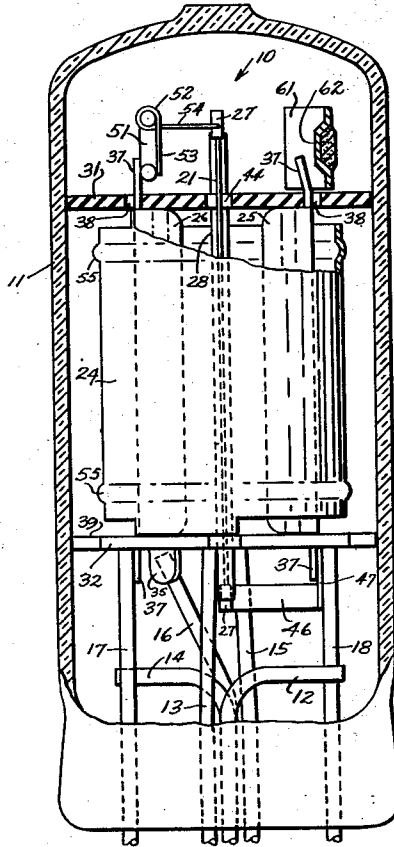


FIG. 2

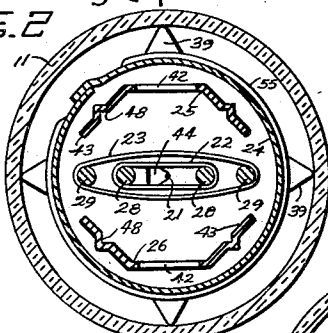


FIG. 4

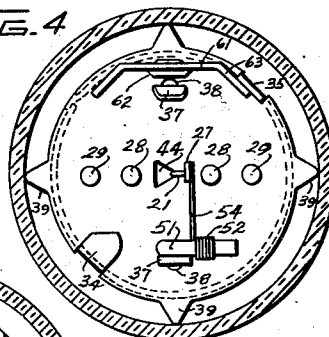


FIG. 5

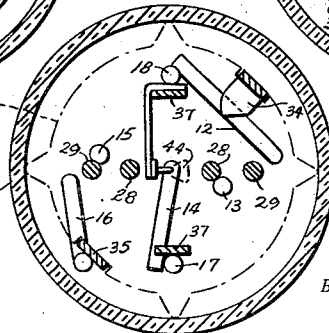
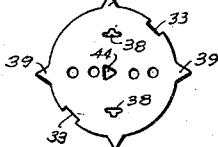


FIG. 4A



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2 SHEETS—SHEET 2

FIG. 6

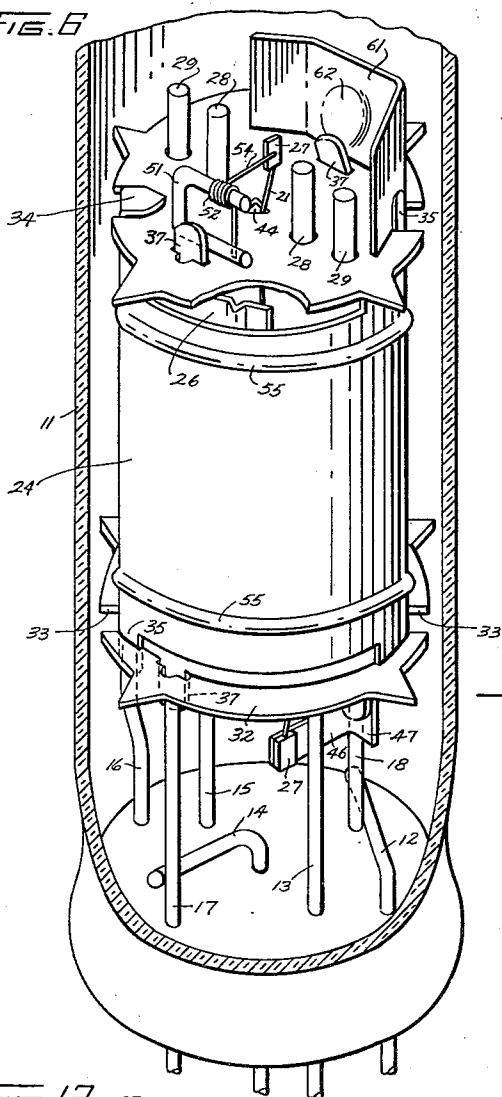


FIG. 7

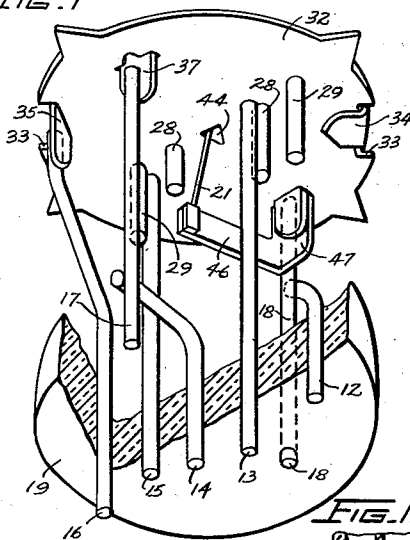


FIG. 10A

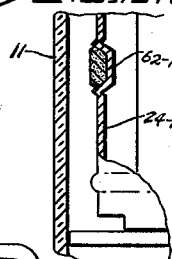


FIG. 8

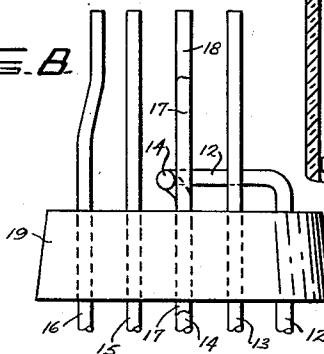


FIG. 9

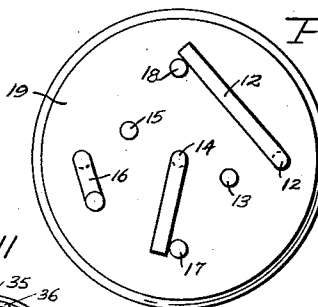


FIG. 12

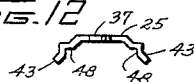


FIG. 10

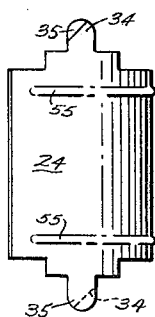


FIG. 13

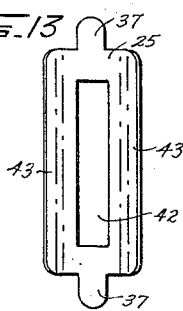
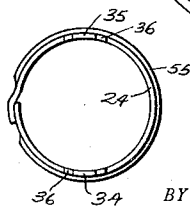


FIG. 11



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ELECTRODE AND ENVELOPE ASSEMBLY FOR
MULTIELECTRODE SPACE DISCHARGE
DEVICESHerbert R. Jacobus, Jr., White Plains, N. Y., as-
signor to Sonotone Corporation, Elmsford,
N. Y., a corporation of New York

Application January 26, 1949, Serial No. 72,985

7 Claims. (Cl. 313—243)

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This invention relates to electron space charge devices in which an electrode assembly comprising an anode, a cathode and at least one grid or control electrode interposed between the cathode and the anode, are enclosed in a hermetically sealed envelope, and more particularly to such electron discharge devices which are known commercially as "subminiature electron tubes," although some of the features of the invention are applicable to electron space discharge tubes other than subminiature tubes.

Among the objects of the invention are subminiature tubes embodying novel features which make it possible to materially reduce their overall volume and to simplify the critical problems connected with their manufacture and to make 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 subminiature tube exemplifying the invention, the tube being shown in a scale of about 1 to 8;

Fig. 2 is a cross-sectional view of the tube along line 2—2 of Fig. 1;

Fig. 3 is a vertical cross-sectional and partially elevational view of the same tube along line 3—3 of Fig. 2;

Figs. 4 and 5 are cross-sectional views along lines 4—4 and 5—5 of Fig. 1, respectively, Fig. 5 showing the bottom spacer in phantom by dash-dot lines;

Fig. 4-A is a plan view of the upper spacer of the tube;

Fig. 6 is a perspective view of the electrode assembly of the tube, as seen from the top;

Fig. 7 is a perspective view of the bottom part of the electrode assembly;

Fig. 8 is an elevational view of the transverse, flat end wall or stem of the tube envelope with the electrode contact leads sealed therethrough before their inner ends are joined to the electrodes of the electrode assembly;

Fig. 9 is a top view of the end row or stem shown in Fig. 8;

Figs. 10 and 11 are elevational and plan views of the anode structure of the tube shown in Figs. 1 to 7;

Figs. 12 and 13 are elevational and plan views of the auxiliary electrode of the tube shown in Figs. 1 to 7; and

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Fig. 10-A is a detailed view similar to Fig. 1, showing a modified construction, in which a part of the anode positioned adjacent to a grid post, is shaped to form an outwardly facing getter compartment.

There are many applications requiring multi-electrode electron amplifier tubes of the subminiature type, having extremely small dimensions and able to operate with a high degree of efficiency and with uniform desirable operating characteristics. Among such applications are hearing-aid amplifiers, proximity fuses, and radio broadcast receivers of a miniature size suitable for hidden wear in the pocket of the user, and other applications in which a minimum of space is a critical factor. Although the principles of the invention are applicable to other types of subminiature tubes, and some aspects of the invention are of a broader scope, their application will be described in connection with a pentode-type tube shown in Figs. 1 through 7, which has a very wide use as a voltage gain and power amplifier.

The tube shown comprises an evacuated, generally elongated tubular envelope 11 of vitreous material such as glass, which encloses an electrode assembly generally designated 10, having a plurality of electrodes which are connected to a plurality of leads 12, 13, 14, 15 and 16, hermetically sealed through an electrically insulated terminal end wall portion 18 of the envelope 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 lead conductors 12 to 16 held generally aligned in a plane vertical to the plane of the stem. The wafer-like lead stem 19 extends in a direction transverse to the envelope and is fused to its lower end border.

The electrode assembly comprises a filamentary cathode 21, a control grid 22, a screen grid 23, and an anode 24, all extending longitudinally generally parallel to a common axis of the electrode assembly, as seen in Figs. 1 and 2, and an additional auxiliary electrode structure having two auxiliary electrodes or electrode sections 25, 26, interposed across the electron path between the anode 24 and the screen grid 25. In the tube shown, the filamentary cathode 21 is made of a thin filament of a refractory metal such as tungsten, provided with an oxide coating which emits electrons when the filament is heated to an elevated temperature. The two opposite ends of the filamentary cathode 21 are provided with mounting portions in the form of metal strips

or tabs 27 to which the ends of the filament are secured as by welding, and which are in turn secured to cathode supports which support the filamentary cathode in its proper operative position.

The two grids 22, 23 are made of very fine refractory metal wire, for instance, tungsten wire about .001" and .0015" in diameter, the inner grid 22 being wound as a helix on and secured to two inner side rods or grid posts 28, and the outer grid 23 being similarly wound and supported on two outer side rods or grid posts 29. The grid posts of such subminiature tubes are usually formed of thin wires, for instance, the inner grid posts of wire about .015" diameter, and the outer grid posts of wire about .020" diameter.

The grid posts as well as the cathode 21, anode 24 and the two auxiliary electrodes 26 of the electrode assembly are held in their operative position by two similar generally flat sheet-like insulating spacer elements 31, 32, made of a material having a high dielectric constant. The two sheet-like spacers 31, 32 are provided with apertures or openings engaged by junction or supporting ends of the grid posts and of the other electrodes which are joined by the spacers into a self-supporting electrode assembly.

The anode 24 is made of sheet metal, and is arranged to receive the electrons emitted by the cathode filament under the control of the control electrode, in a manner well known in the art. In all prior subminiature tubes the anode was held in its properly spaced operative position relatively to the other electrodes of the electrode assembly by junction portions or supporting rods seated in openings of the insulating spacers. Since the anode structure of such tubes forms the outermost part of the electrode assembly, the insulating supporting spacers on which the opposite ends of the anode supporting rods are retained, had to be made of sufficient width to serve as an anchorage not only for the grid posts but also for the junction elements of the anode.

According to one phase of the invention, a material reduction of the width and the over-all volume of the electrode assembly—a critical factor in subminiature tubes—is made possible by providing an exposed peripheral edge regions of the two insulating spacers 31, 32 with spaced retainer recesses 33, and by forming the opposite boundary edges of the anode sheet structure 24 with a plurality of spaced sheet tongue portions interlockingly engaging and interfitting with the retainer recesses of the two spacer members, so as to secure the two spacers 31, 32 to the unitary tubular anode sheet structure and join them into a self-supporting assembly structure.

As shown in Figs. 1 to 7, and in detail in Figs. 10 and 11, the anode 24 is made in the form of a cylindrical tubular sheet structure of thin refractory metal, such as nickel. Each of the opposite generally circular boundary edges of the anode 24 has two spaced sheet ears or tongues 34, 35, interlockingly engaging and interfitting with the two spaced retainer recesses 33 of the two opposite spacer members 31, 32, so as to secure the two spacers 31, 32 to the upper and lower ends of the tubular anode 24 and join them into a self-supporting assembly.

The junction tongues 34, 35 of the anode are provided with intermediate shoulder portions 36 against which the two spacers 31, 32 abut when they are joined to the anode structure, to provide

annular gap spaces between the major part of the circular boundary edges of the anode 24 and the facing portions of the mica spacers 31, 32, and limit to a minimum the area along which they make direct contact with the metallic anode.

As is well known, as a part of the evacuation process, the metallic anode structure has to be heated to a high temperature of about 900° C., in order to de-gas it. On the other hand, the mica insulating spacers comprise hydrates which decompose when heated to an excessive temperature, weakening the spacer sheet structure and reducing its resistance to electric leakage, a phenomenon known as "puffed mica." By limiting the contact area between the relatively large anode sheet structure and the mica insulating spacers joined thereto to the small edge surface portions of the junction tongues of the tubular anode and the recess edge-regions of the spacers, the flow of heat from the anode maintained at a high temperature to the spacer body, is kept down, and damage to the mechanical and insulating characteristics of the insulating spacers 31, 32 is avoided.

The annular gap spaces between the circular boundary edges of the anode 24 and the insulating spacers 31, 32 provide windows through which the interior elements of the electrode assembly enclosed by the anode, and their proper mounting and spacing, may be illuminated and visually inspected.

The interlocking engagement of the anode junction tongues 34, 35 with the peripheral retainer recesses 33 of the two spacers 31, 32 provides a good mechanical interconnection therebetween and joins them into a self-supporting mechanical structure, provided the anode tongue portions 34, 35 are slightly bent in inward direction after the two spacers 31, 32 have been fitted with their recesses over the tongues against the tongue shoulders 36. It is not necessary to bend the end portions of the anode tongues 34, 35 over the outer surfaces of the spacers in order to provide such good operative mechanical interconnection between the anode and the two spacer elements so supported thereon.

As shown in Figs. 1 to 7, to provide a stronger interconnection between the anode 24 and the two spacers 31, 32, both anode tongues or only one anode tongue, such as tongue 34, of each boundary edge of the anode, may be bent as much as about 90° against the outer surface of the respective adjoining spacer members 31, 32, without bringing the tongue portion overlying the spacer into direct contact engagement therewith.

As shown in Figs. 1 to 5, each of the insulating sheet spacers 31, 32 is also provided with resiliently yieldable spacer projections 39 which are shaped to engage the inner surface of the tubular envelope 11 and serve to maintain the anode and the entire electrode assembly in the properly spaced and aligned position within the envelope when the electrode assembly is inserted into the envelope from the bottom end thereof before the stem portion 18 thereof with the leads sealed therein is properly joined and sealed to the side walls of the envelope.

In the tube of the invention, an auxiliary electrode structure formed of the two auxiliary electrodes 25, 26 of sheet metal, is utilized as a shielding or suppressor electrode for shielding the electron discharge space against secondary electron emission from the anode, and for giving the tube the desired operating characteristics.

As shown in Figs. 1 to 7, and in detail in Figs.

12 and 13, two auxiliary shield electrodes 25, 26 are made of elongated strips of a refractory sheet metal, having at its opposite end edge portions junction tongues 37 seated in elongated openings or slits 38 of the opposite insulating spacers 31, 32 for holding the sheet electrodes 25, 26 in their proper operative position within the electrode assembly. The two auxiliary shield electrodes 25, 26 are positioned so that they provide wide sheet surfaces which are spaced from the cathode 21 and the anode 24 by about the same distance as the grid posts 29 of the screen grid 23, and which extend transversely across the path of the electrons from the cathode 21 across the two grid electrodes 22, 23 towards the facing arcuate regions of the circular anode 24. Each auxiliary sheet electrode 25, 26 has a central wall portion 41 having elongated electron beam openings 42 confining the beam of electrons passing from the cathode to the anode, and two wings or side wall portions 43 bent inwardly toward the region of the grid posts 29, so that when the two auxiliary electrodes 25, 26 are maintained at the cathode potential, the flow of electrons between the cathode 21 and the anode 24 will be confined to the two beam openings 42 of the opposite auxiliary electrodes 25, 26. Since the manner in which such auxiliary electron-intercepting electrodes operate is well known in the art—as described, for instance, in the U. S. Patents to Schade, 2,107,520; Strutt, 2,205,500; and Schoenberg, 2,113,801; and in the British Patent No. 324,175—no further description of their operation is required. When used in space charge tubes operating as gain and power amplifier tubes, such auxiliary electrodes 25, 26 of the tube of the invention shown, are connected to the opposite ends of the filamentary cathode 21 and maintained at the cathode potential.

In the tube shown, the two insulating spacers 31, 32 of the electrode assembly have in addition to the slit openings 38 for the junction tongues 37 of the auxiliary electrodes and the openings for seating the junction ends of the two sets of grid rods 28, 29, a generally central opening 44 of triangular shape to provide at the vertex of two angular edges thereof a positive seat against which spaced seating portions of the cathode filament are held seated and positioned in proper spacing relatively to the other electrodes.

For satisfactory operation of such discharge tubes, it is essential that the effective portion of the filamentary cathode 21 facing the operative portions of the other electrodes shall be held stretched under tension in a predetermined desired operative position. Because of the close electrode spacing, the problem of connecting the opposite ends of the thin filamentary cathode to proper tensioning supports which hold the cathode filament tensioned and biased against the angular positioning recesses of the two spacers, is critical, particularly if such tubes are to be manufactured at low cost on a mass production basis.

The required tiny connector elements by means of which the opposite ends of the filamentary cathode are connected and held tensioned in the operative position to the electrode assembly, are so arranged as to make it possible to readily align the connector elements with junction elements of the filamentary cathode and of the co-operating supporting parts of the electrode assembly, and to readily join the aligned elements in positions in which they automatically operate to maintain the cathode in the desired operative tensioned condition.

As shown in Figs. 1, 2 and 7, the lower mounting tab 29 of the filamentary cathode 21 is supported in its operative position by a generally L-shaped metallic connector strip 46 having one arm to which the mounting tab 27 of the filamentary cathode 21 is secured as by welding. The connector strip 46 has an arm 47 angularly bent relatively to its longer arm and secured to the lower junction tongue 37 of the auxiliary electrode 25 projecting beyond the outer side of the lower spacer 32. The width of the connector strip arm 47 is substantially equal to the width of the projecting junction tongue 37 of the sheet electrode 25 to which it is secured, thereby enabling the operator to place them in aligned overlapped positions in which they are secured, as by welding. This connector strip arrangement obviates the necessity for using judgment and care when securing the connector strip 46 in its proper operating position to the junction tongue 37 by means of which it is supported on the outer side of the electrode spacer 32.

As seen in Figs. 1, 5 the arm of the connector strip 46 to which the bottom mounting tab of the filamentary cathode 21 is secured, is made of such length that when the filament mounting tab 27 is secured in a position where the edge of the tab 29 is substantially aligned with the end edge of the connector strip 46, the latter will automatically bias the bottom portion of the filamentary cathode 21 into seating engagement with the vertex of the angular recess of the opening spacer 44 through which it passes.

As seen in Figs. 1 to 7, by mounting the two auxiliary sheet electrodes 25, 26 so that they extend between the narrow sides of the generally flat or oblong grid electrodes 22, 23, in the manner shown, the bottom junction tongue 37 of the auxiliary sheet electrode 26 which serves as a support for the cathode connector strip 46, provides for a relatively long connector spring arm extending in a direction generally perpendicular to the desired direction of the biasing seating forces which are exerted by it on the end portion of the filamentary cathode 21 connected thereto. With this arrangement of the auxiliary sheet electrodes 25, 26, the central portion 39 of each auxiliary sheet electrode provided with the beam opening 42 extends in a plane substantially perpendicular to the plane defined by the grid posts or the long axis of the grid electrodes 22, 23, and the L-shaped connector strip 46 connecting the junction tongue 37 of sheet electrode 26 to the cathode tab 27 of the cathode 21 provides a relatively long elastic biasing arm exerting the desired cathode biasing forces in the direction perpendicular to the direction of its length.

The generally L-shaped structure given to the cathode connector strip 46, 47, as seen in Figs. 1, 5 and 7, facilitates not only ready alignment of its ends with respect to the elements to which they have to be connected, but also greatly simplifies the problem of welding its short arm 47 to its supporting junction tongue 37. To perform such welding operation, one of the welding electrodes may be placed against the inner surface of the bottom junction element 37 of the auxiliary sheet electrode 25 through the gap space between the longer arm 45 of the connector strip and the outer surface of the spacer 32, while the other welding electrode is placed against the outer surface of the short connector strip arm 47 held against the junction element 37, in which position the welding current is passed between the welding electrodes.

As shown in Figs. 1, 3, 4 and 6, the upper end of the filamentary cathode 21 is held tensioned and biased against the angular corner recess of the central opening 44 of the upper insulating spacer 31 by a tensioning connector structure including a reversely bent generally U-shaped connector rod 51 and a coil spring 52. The rear portion of the lower arm of the metallic U-shaped connector rod 51 is affixed, as by welding, to the outwardly projecting junction tongue 37 of the auxiliary sheet electrode 26. The coil spring 52 comprises a plurality of helical turns coiled loosely around the free arm of the connector rod 51, and has one spring end arm 53 restrained from movement by affixing it as by welding to a freely projecting portion of the lower arm of rod 51. The other end of the loose coil spring 52 terminates in a substantially straight relatively long spring arm 54 to the end region of which is secured as by welding, the upper mounting tab 27 of the cathode filament 21. The supporting rod member 51 is held aligned in the direction of its length by the tongue portion 37 of the sheet electrode 26 to which it is secured in a direction generally parallel to the direction of the biasing forces which the free spring arm 54 has to exert on the upper end of the filamentary cathode 21 for holding it biased against the corner recess of the supporting opening 37 of the top spacer 31.

Because of this arrangement, the coiled spring tensioning support member 52 of the cathode support may be readily placed in its operative position on the U-shaped rod member 51 and secured thereto in its proper operative position in which its free spring arm 54 exerts the desired elastic and biasing tensioning forces on the cathode filament affixed thereto. This arrangement facilitates the securing of the U-shaped rod member 51 of the cathode tensioning spring coil 52 in its proper aligned mounting position by merely aligning the rear end of the lower arm against the edge of the projecting sheet tongue 37 of the auxiliary sheet electrode 26 and welding them to each other by a simple welding operation. With the U-shaped rod member 51 so secured in its aligned operating position, its freely projecting upper arm is ready to receive and hold the coil spring 52 in a position in which its free cathode tensioning arm 54 will automatically exert on the top end of the filamentary cathode 21 secured thereto, the desired tensioning and biasing forces which cause the filament portion passing through the upper cathode opening 44 of the spacer 31 to be moved along the angular recess edges to the corner seating recess and supporting it therein in proper operative tensioned position.

The arrangement of the connector rod 51 with its coil spring 52 shown, makes it possible for the operator to secure the U-shaped mounting rod of the cathode tensioning coil spring 52 in the properly aligned position by merely aligning the intermediate or center portion of the U-shaped supporting rod 51 in overlapped relation with the edge of outwardly projecting junction tongue 37 of the auxiliary sheet electrode 26, with the two rod arms extending substantially parallel to the adjacent outer surface of the spacer 31, and to weld the rear portion of the inward rod arm to the overlapping portion of the tongue member 37 by applying to the overlapping rod arm and tongue portions the welding electrodes and passing the welding current. When so welded, the two arms of the rod 51 project freely from electrode tongue 37. The coil spring 52 may thereupon be readily slipped on the upper free arm

of the rods and retained in a properly aligned support, in which position the free straight spring arm 54 exerts the desired cathode positioning and tensioning forces on the cathode filament 21.

To provide the desired aligned assembly, it is sufficient to align the transverse intermediate junction section of the mounting rod member 51 with the edge of the sheet tongue 37 to which it is to be secured, in a position in which the inward arm of the mounting rod 51 is placed at some small distance from the insulating spacer 31 substantially parallel to the plane of the spacer. The coil spring 52 is then readily slipped over the free end of the upper rod arm of rod member 51 until the free spring arm 54 is aligned with the opposite edge of the sheet tongue, as shown in Fig. 4. Thereupon the other spring arm 53 is welded to the inward rod arm of rod member 51, in a position which automatically assures that the free arm of spring arm 54 will be held in a position in which it exerts, on the cathode filament 21 secured thereto, the desired tensioning and sealing forces.

As shown in Figs. 1, 3, 4 and 8, the upper junction tongues 35 of the tubular anode 24 has secured thereto a getter support in the form of a metal strip 61 extending generally parallel above the outer surface of the upper insulating spacer 31. The getter support strip 61 has formed therein a pocket 62 with an opening facing the adjacent side wall portion of the envelope and a body of getter material held affixed within the pocket.

The getter support strip 61 is bent to generally conform to the tubular shape of the envelope, and has a central portion provided with the getter pocket 62 and two arms or wings extending therefrom so as to constitute barriers which confine evaporated vapors of the getter material to the region of the envelope facing the outer surface of the getter support 61 and substantially prevent getter vapor from materially reducing the surface leakage resistance of the insulating spacer 31 adjacent to which it extends.

To keep the height and size of the tube structure to a minimum, the getter support strip 61 is arranged to constitute in effect a short outward extension of an arcuate portion of the cylindrical anode structure. With such arrangement, the getter structure does not increase the size of the electrode structure, since it occupies the region immediately above the outer surface of the upper insulating spacer which has substantially the same height as the opposite region in which the cathode tensioning support elements 51, 52 are positioned.

One side wing of the generally arcuate getter support 61 forms a junction portion 63 thereof, which is secured as by welding to the anode junction tongue 35. The junction portion 63 of the getter support strip 61 is secured to the outwardly projecting tongue portion 35 of the anode in a position in which an edge of the junction portion 63 substantially engages the adjacent surface portion of the insulating spacer 31, so as to retain the spacer 31 against displacement in axial direction away from the seating shoulder portion 36 of the tongue 35.

In order to prevent overheating of the insulating body of the spacer 31 when the getter strip 61 is heated to the high temperature at which the getter body evaporates, the edge portion of the getter support strip 61 extending beyond its junction portion 63 is spaced by a small gap from the adjacent surface portion of the

insulating spacer 31, in the manner indicated in Figs. 1 and 3.

By the arrangement shown, the getter support with its getter is confined to a short region of the height of the tube substantially coextensive in height with the region in which the cathode tensioning supporting elements are confined, thus making it possible to reduce the overall length or height of the tube to that occupied by the actual elements of the electrode assembly.

With the stem arrangement of the invention described above, the inward portions of the leads may be readily so arranged that a substantially straight or slightly bent lead portion extending from the stem in a direction generally parallel to the axis of the electrode assembly will provide a lead connection from the electrode to the external circuits. This assures a "clean" combined electrode and stem assembly, with all connector elements extending between the electrode assembly and the external terminal connections being readily accessible for manipulation, and joining by welding or the like. In addition, this arrangement greatly increases the ruggedness of the combined electrode assembly, and gives all interconnecting elements between the electrode assembly and the base greatly increased structural strength for withstanding the strains imposed thereon when such tube is exposed to the enormous acceleration forces in applications such as proximity fuses on projectiles.

In the form shown, the ends of the inward portions of leads 13, 15 and 16, which are parts of the main row of terminal leads 12 through 16, and the adjacent junction ends of the grid side rod 28 of the inner grid 22, the junction ends of grid side rod 29 of the outer grid 23, and the junction tongue 35 of the anode, respectively, all extend substantially parallel to the axis of the electrode assembly.

The inward portions of the two leads 17, 18, which are aligned in a row which is generally transverse to the main row of leads 12 through 16, likewise extend into engagement with the junction ends 37 of the two shield electrodes 25, 26, to provide connections to the two shield electrodes and therethrough to the filamentary cathode 21, the opposite ends of which are connected between shield electrode 25 and shield electrode 26.

The inward portions of the several leads 13, 15, 16, 17, 18, terminate substantially in a plane transverse to the tube axis, so that the inner ends of the several leads may be readily aligned adjacent the junction elements of the electrodes to which they are to be joined and respectively secured thereto by simple welding operations.

The outward portions of leads 17, 18, which are aligned in a plane transverse to the plane of the main row of leads 12 through 16, are cut off slightly beyond the outer flat surface of the stem 19 as they emerge therefrom.

To provide external terminal connections to the electrodes to which the inward lead portions 17, 18 are connected, the inner portions of leads 12 and 14 are bent to form connector elements which join their outward prong portions to the inward lead portions 17, 18, which provide the connections to the shield electrodes described above. It will be noted that the inwardly bent portions 12, 13 extend near the inner flat surface of the stem 19 at a sufficient distance therefrom to permit easy welding of the bent ends of the inner leads 12, 13 to the straight inner portions of leads 17, 18.

By securing the inner ends of the several electrode leads 13, 15, 16, 17, and 18, which are displaced from a plane, to the junction portions of the electrode assembly at points where they emerge beyond the outer surface of the bottom spacer 32, the ends of the inner lead extensions serve also as retainers which retain the lower spacer 32 against axial displacement relatively to the electrode assembly.

In such subminiature tubes, the close, critical spacing between the cylindrical anode 24 and the two auxiliary sheet electrodes 25, 26 with their electron beam defining openings 42 relatively to each other and to the other electrodes of the electrode assembly, makes it essential to assure that their relative shape and spacing is not disturbed when the junction tongue portions of the electrode sheet members 24, 25 and 26 are bent or subjected to strains while joining them into the electrode assembly described above, or through the forces exerted thereon by the connector elements joined thereto, such as the cathode biasing and supporting connector elements 46, 51, 52, joined to the tongue junction portions of the two auxiliary sheet electrodes 25, 26.

In accordance with one phase of the invention, the cylindrical tubular anode structure 24 is provided, at two spaced portions of its length adjacent to the end regions thereof, with arcuate channel formations 55 extending in a direction transverse to its axial length, so as to materially increase the stiffness of the anode structure against deformation of its cylindrical shape when the tongue junction portions 34 there are bent in the procedure of joining the two insulated spacers 31, 32 to the opposite ends of the anode structure.

Furthermore, in accordance with a phase of the invention, the two side wall portions 43 of each of the auxiliary sheet electrodes 25, 26 are provided with an elongated channel formation 48 generally parallel to their axial length for materially increasing their stiffness and substantially preventing disturbing deformations thereof and of their beam openings by bending or other forces applied to their junction tongues 37.

In order to enable those skilled in the art to readily practice the invention, and without in any way limiting its scope, there are given below data for a tube of the invention, which proved highly satisfactory when used as a gain amplifier:

The insulating mica spacers 31, 32 are about .006" to .010" thick, and are .220" in diameter, and are spaced by a distance of .315". The center distance between the outer grid posts is .125". The center distance between the inner grid posts is .065". The distance between the mounting slits of the auxiliary sheet electrodes is .120".

The cylindrical anode is of nickel or stainless steel sheet material, .005" thick and is .188" in diameter.

The auxiliary sheet electrode is made of nickel or stainless steel sheet material .007" thick, their width is .143", and their beam opening is .25" by .062".

The getter support is .093" high.

The cylindrical glass envelope has an inner diameter of .251", an outside diameter of $\frac{5}{16}$ ", and a length slightly more than $\frac{3}{4}$ ".

The tube may be designed for operation with a filament current of 20 milliamperes, 15 milliamperes, or 10 milliamperes, with a voltage of .065 volt across the filament. When operating with

a plate voltage and a screen voltage of 22.5 volts, and a plate current of 200 microamperes, it has a transductance of 100 micromhos and a plate resistance of 1 megohm.

Similar tubes with a distance of .600" between the insulating spacers 31, 32, and correspondingly longer electrodes, will serve as a power tube. With the filament designed for operation with a filament voltage of 1.25 volts and a filament current of .020 ampere, such power tube operating with a plate voltage and screen voltage of 22.5 volts and a control grid voltage of -0 volts, and a plate current of 500 microamperes, has a transductance of 400 micromhos, and a plate resistance of 170,000 ohms. It has a power output of 4.0 milliwatts at 12% distortion.

As indicated in Fig. 10-A, an outwardly facing surface portion of the sheet metal of the anode—other than that facing the electrode beam opening of a shield electrode—may be formed as by a shaping operation into an outwardly facing getter pocket 62—similar to the getter pocket of the getter support 61 for holding a body of getter material which is evaporated subsequent to the evacuation and sealing operation. Since the mass of the anode is extremely small, and of the order of the mass of the getter supports generally used in tubes, such arrangement eliminates the necessity of a separate getter support, in accordance with the principles of the co-pending Herbert D. Suesholtz et al. application Serial No. 633,670, filed December 8, 1945, now Patent No. 2,464,272.

The subminiature tube of the invention of the type described, may be readily manufactured by the following procedure:

The upper insulating mica spacer 31 is placed with its top surface on an upwardly facing assembly jig with its inner surface facing upwardly. The junction ends of the two grid posts 28, 29 of the inner grid 22 and the outer grid 23, respectively, are then inserted into the corresponding openings of spacer 31. The junction tongues 37 of the two auxiliary suppressor sheet electrodes 25, 26 are then inserted into the junction slit 38 of the upper spacer 31, whereupon the cylindrical anode 24 is slipped over the so-positioned electrodes 22, 23, 25, 26 and the junction tongues 34, 35 of the anode 24 are inserted into the recesses 33 of the top spacer 31 while held in position on the assembly jig.

The bottom spacer 32 is then positioned above the so-assembled electrodes 22, 23, 24, 25, 26, and its openings and recesses are slipped over the bottom junction ends of the grid posts 28, 29, and the bottom junction tongues 37 and 34, 35 of the suppressor electrodes 25, 26 and of the anode 24, respectively. With the several electrodes and the two spacers held in inverted position on the assembly jig, the anode junction tongue 34 is bent about 90° over the outer surface of the bottom mica spacer, and the other anode tongue 35 is temporarily bent slightly inwardly, thereby assuring that the bottom spacer 32 will be retained in its assembled position on the cylindrical anode (Figs. 1, 5 and 9).

The electrode assembly is then turned 180° to bring the top spacer 31 to a position in which it faces upwardly. The upper anode junction tongue 34 is then bent about 90° over the outer surface of the spacer 31, and the other anode junction tongue 35 is temporarily slightly tilted inwardly to assure that the upper spacer 31 is retained on the cylindrical anode 24 (Figs. 3, 13). In addition, the top junction tongue 37 of the

suppressor electrode 25 is slightly tilted in inward direction to assure that it does not make contact with the getter pocket 62 of the getter support 61 when the latter is secured to the assembly (Figs. 1, 2, 13).

After removing the electrode assembly from the assembly jig, the L-shaped cathode connector strip 46 is placed with its junction arm 47 in overlapping alignment against the coextensive bottom junction tongue 37 of the suppressor electrode 25, and secured thereto by welding. The U-shaped spring-mounting rod 51 of the cathode tensioning coil spring 52 is placed in the aligned position shown, with its two arms aligned in the plane of the top tongue 37 of the suppressor electrode 26 and extending parallel to the plane of the spacer 31, and with the inner arm of the rod 51 overlappingly aligned with one edge of the screen tongue 37 secured thereto by welding, so that the upper free arm of rod 51 extends generally parallel to the plane of the biasing forces exerted by the free spring arm 54 on the cathode filament 21.

In a separate sub-assembly operation, the upper mounting tab 27 of the cathode 21 is secured in aligned position to an end portion of the free spring arm 54 in a direction generally perpendicular thereto, so that when the spring coil 52 is placed on the free arm of U-shaped rod 51, the free spring arm 54 will exert on the top end of the cathode filament 21 biasing and tensioning forces in the direction of the plane defined by the grid side rods 28, 29.

The filamentary cathode 21 carried freely suspended in a vertical position by the end portion of the straight spring arm of the coil spring 51 is then dropped or threaded with its lower end through the relatively large aligned central cathode openings of the two spacers 31, 32 of the electrode assembly. The coiled turns of the coil spring 52 are then slipped over the free upper arm of the U-shaped mounting rod 51. The lower cathode mounting tab 27 is then welded to the end of the free arm of the L-shaped connector strip 46, the other arm of which has been previously secured in aligned overlapping position to the bottom tongue 37 of the suppressor electrode 25. The short spring arm 53 of the coil spring 52 is then gripped and brought against the lower arm of the U-shaped mounting rod 51 and welded thereto in a position in which the free arm 54 of the coil spring 52 extends substantially above the grid side rod 28, which is next to the angular filament seating recess of the spacer opening 44 (Fig. 3). In this position the free spring arm 54 exerts the desired elastic tensioning and biasing forces which maintain the cathode filament 21 tensioned and biased to come into seating engagement with the vertex of the angular recess of the cathode seat openings 44 of the two spacers 31, 32.

The end portion 63 of the getter support strip 61 is then placed in overlapping alignment with the upper anode tongue 35, and welded thereto, the tongue 35 having been straightened before performing the welding operation, since the welded end of the getter strip 61 now serves to retain the spacer 31 against axial displacement.

By the foregoing operations, all the elements of the electrode assembly including the cathode and its tensioning and biasing support, are all joined and secured to each other into a complete self-supporting electrode assembly in which substantially all operative parts occupy their final operative position, in which the proper re-

relationship and spacing of the individual electrode elements may be inspected and checked.

The electrode leads are welded to the junction ends of the several electrodes as a part of the assembly operation described above, as follows:

Lead 16 is welded to the adjacent junction end of grid rod 29 of the outer grid 23. Lead 14 is welded to the adjacent junction end of grid rod 28 of the inner grid 22. Lead 17 is welded to the junction tongue 35 of the anode 24, which has been previously bent to retain the spacer, but which has been straightened out before performing the welding operation, since the inner ends of at least two of the electrode leads 13 to 17 now serve to retain the spacer 32 against axial displacement. A connector strip or ribbon 34 has one end thereof welded to the junction tongue 37 of suppressor electrode 25, and the other end of the connector ribbon 34 is welded to the inner end of the lead conductor 13. The inner end of lead 15 is then welded to the bottom junction tongue 37 of the suppressor electrode 26.

With the foregoing operation, the electrode assembly has been joined by the electrode lead conductors to the transverse lead stem 18 through which they are sealed, with all elements of the co-completed assembly held in their final operative position, in which their relationship and spacing may be inspected and checked. Notwithstanding the extremely close spacing of the tiny electrodes of the sub-miniature tube of the invention, the foregoing assembly operations may be readily performed by relatively unskilled labor after only short training, and the entire sequence of the foregoing assembly operations requires less time than reading the foregoing description thereof.

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 exemplifications of the invention described above.

I claim:

1. In an electron space discharge device housed in a sealed tubular envelope: an assembly of electrodes extending longitudinally generally parallel to a common axis including a tubular anode of sheet metal, and at least two additional electrodes and a filamentary cathode surrounded by the anode; two spaced, generally flat sheet-like insulating spacers extending transversely to said axis and having two transversely disposed rows of spacer openings holding the opposite ends of said electrodes in their operatively spaced positions; each of said two rows of spacer openings including a common central spacer opening and two outward spacer openings spaced by a distance from said central spacer opening; each spacer having four peripherally displaced spacer projections aligned with said four outward spacer openings and engaging the inner surface of the envelope for spacing said assembly from the envelope; the peripheral edge of each spacer having at least two spaced retainer recesses each of small depth and relatively large width and positioned between two spacer projections thereof in positions angularly displaced relatively to said two rows of spacer openings; each of the opposite ends of said tubular anode having at least two junction sheet tongues extending from the edge thereof and interlockingly

engaging and interfitting the two spaced recesses of said two spacers for securing said two spacers to said anode and joining them and said electrodes into a self-supporting electrode assembly.

2. In a space discharge device as claimed in claim 1, at least a portion of one tongue of each end of said tubular anode being bent over the exterior surface of the edge portion of the spacer recess engaged thereby for fixing said one spacer against axial displacement, a getter structure of sheet metal having a sheet portion secured to the other tongue at one end of said anode and extending over an adjacent outer surface portion of the spacer for fixing said spacer against axial displacement; an electrode lead secured to the other tongue at the other end of said anode and extending over and adjacent outer surface portion of the spacer for fixing said spacer against axial displacement.

3. In an electron space discharge device: an assembly of electrodes extending longitudinally generally parallel to a common axis, including a tubular anode of sheet material, two additional sheet electrodes located between opposite portions of said anode, a filamentary cathode positioned between said additional sheet electrodes, and at least one grid electrode extending between said cathode and said two sheet electrodes; two spaced generally flat sheet-like insulating spacers extending transversely to said axis and holding the opposite ends of said electrodes in their operatively spaced positions; the opposite ends of said two sheet electrodes having junction tongues extending through openings of said spacers; opposite end portions of said cathode extending through cathode openings of said spacer and being held biased against cathode seats of said cathode openings; one connector structure being connected between one cathode end of said cathode and one junction tongue of one sheet electrode at one end of said electrode assembly, and an additional connector structure connected between the other end of said cathode and a junction tongue of the other sheet electrode at the other end of said electrode assembly for exerting biasing forces holding two spaced seating regions of said cathode tensioned and biased against said cathode seats; one of said connector structures comprising a U-shaped rod having one rod arm secured to said one junction tongue, and a coil spring loosely held on the other rod arm and having at its loose end a spring arm secured to said one cathode end, the arms of said U-shaped rod extending substantially parallel to the surface of the adjacent spacer and to the direction of the biasing forces restraining and holding said cathode against said cathode seats.

4. In a discharge device as claimed in claim 3, said U-shaped rod being secured to said junction tongue in a position in which the transverse portion of said U-shaped rod extending between its two arms is substantially aligned with the adjacent side edge of the junction tongue to which it is secured.

5. In an electron space discharge device: an assembly of electrodes extending longitudinally generally parallel to a common axis, including a tubular anode of sheet material, two additional sheet electrodes located between opposite portions of said anode, a filamentary cathode positioned between said additional sheet electrodes, and at least one grid electrode extending between said cathode and said two sheet electrodes;

two spaced generally flat sheet-like insulating spacers extending transversely to said axis and holding the opposite ends of said electrodes in their operatively spaced positions; the opposite ends of said two sheet electrodes having junction tongues extending through openings of said spacers; opposite end portions of said cathode extending through cathode openings of said spacer and being held biased against cathode seats of said cathode openings; one connector structure being connected between one cathode end of said cathode and one junction tongue of one of said sheet electrodes at one end of said electrode assembly, and an additional connector structure connected between the other end of said cathode and a junction tongue of the other sheet electrode at the other end of said electrode assembly for exerting biasing forces holding two spaced seating regions of said cathode tensioned and biased against said cathode seats, said spacer openings forming parts of two rows of spacer openings of each spacer, each row including two outer spacer openings spaced from the center of the spacer; each spacer having four peripherally displaced spacer projections aligned with said two rows of spacer openings and engaging the inner surface of the envelope for spacing said assembly from the envelope, and each spacer having along its edge at least two spaced retainer recesses, each recess being of small depth and relatively large width and being positioned between two spacer projections in positions angularly displaced relatively to said two rows of spacer opening; each of the opposite ends of said tubular anode having at least two junction sheet tongues extending from the edge thereof and interlinkingly engaging and interfitting with the two spaced recesses of said two spacers for securing said two spacers to said anode and joining them and said electrodes into a self-supporting electrode assembly.

6. In a discharged device as claimed in claim 5, said U-shaped rod being secured to said junction tongue in a position in which the transverse portion of said U-shaped rod extending between its two arms is substantially aligned

with the adjacent side edge of the junction tongue to which it is secured.

7. In a space discharge device as claimed in claim 5, at least a portion of one tongue of each end of said tubular anode being bent over the exterior surface of the edge portion of the spacer recess engaged thereby for fixing said spacer against axial displacement, a getter structure of sheet metal having a portion secured to the other tongue and extending over an adjacent outer surface portion of the spacer engaged by said other tongue for fixing said spacer against axial displacement, each of said sheet electrodes having along a central wall region thereof an aperture for passing a beam of electrons between the cathode and the anode, the two side wall regions adjoining the aperture of each of said sheet electrodes having each a lengthwise channel formation extending parallel to said axis for materially increasing the stiffness of the central regions of said sheet electrodes and preventing deformation of their apertures by mounting strains.

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