

June 9, 1953

L. E. CISNE

2,641,726

ELECTRON DISCHARGE DEVICE AND METHOD OF FABRICATION

Filed April 7, 1950

2 Sheets-Sheet 1

FIG. 1

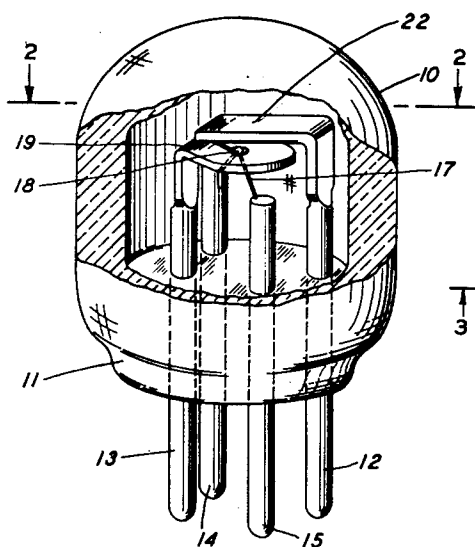


FIG. 2

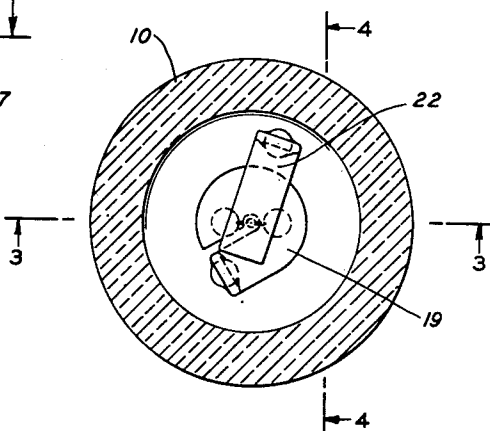


FIG. 3

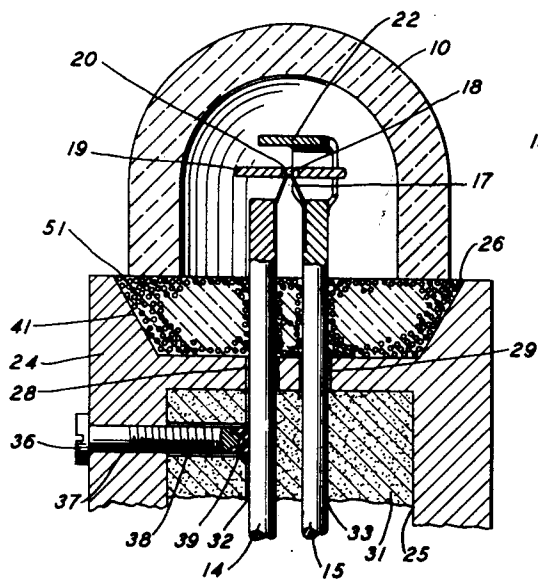
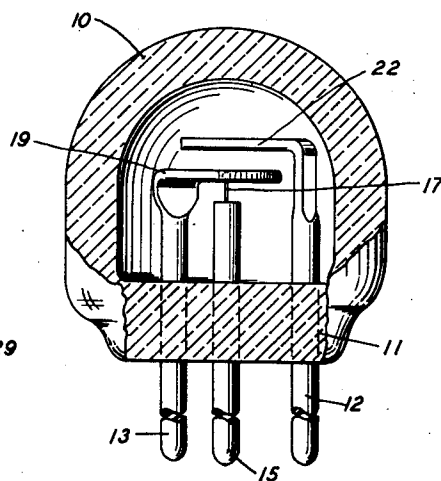


FIG. 4



INVENTOR
L. E. CISNE

BY

[Signature]

ATTORNEY

June 9, 1953

L. E. CISNE

2,641,726

ELECTRON DISCHARGE DEVICE AND METHOD OF FABRICATION

Filed April 7, 1950

2 Sheets-Sheet 2

FIG. 5

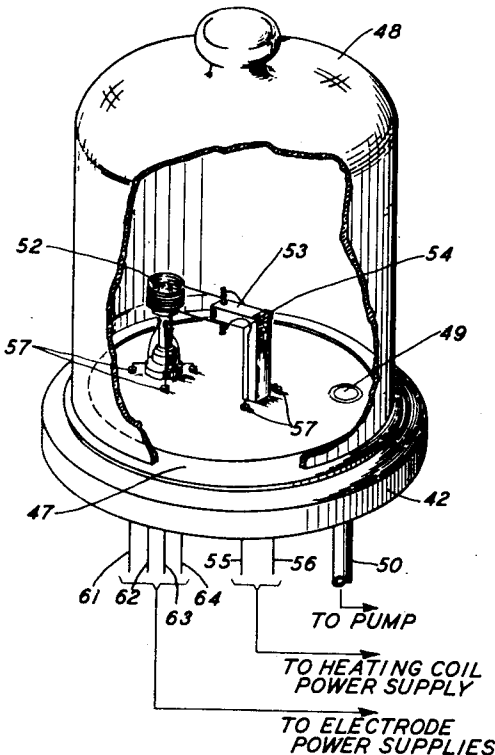
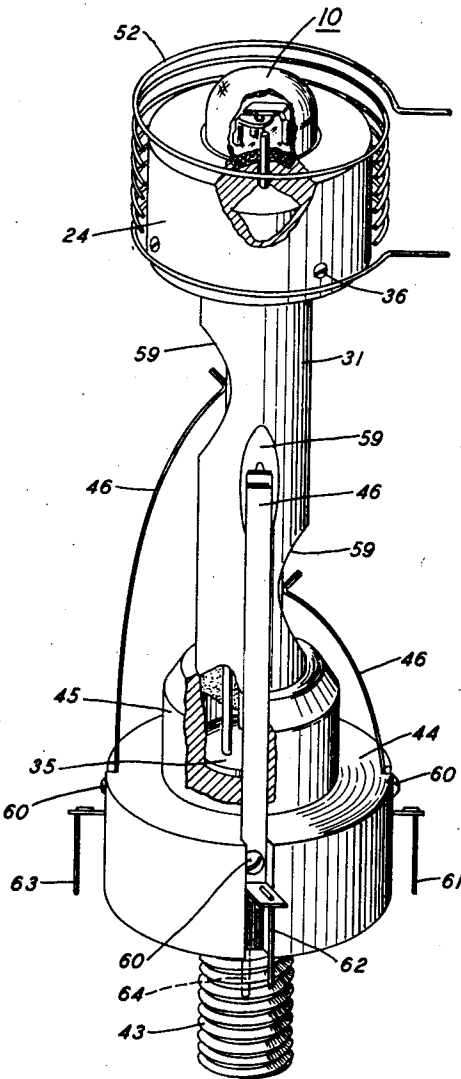


FIG. 6



INVENTOR
L. E. CISNE
BY *[Signature]*
ATTORNEY

UNITED STATES PATENT OFFICE

2,641,726

ELECTRON DISCHARGE DEVICE AND
METHOD OF FABRICATION

Luther E. Cisne, New Providence, N. J., assignor
to Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

Application April 7, 1950, Serial No. 154,575

9 Claims. (Cl. 313-249)

1

This invention relates to electron discharge devices and the method of fabricating such devices, and particularly to extremely small or minute electron discharge devices.

The present trend in equipment design requires that conventional electron discharge devices be replaced by ever increasingly smaller units. These units should be physically smaller, should require lower voltage supplies, have a lower power consumption, and operate with lower filament currents. Various applications for such exceedingly small devices arise, for example, in mobile or carried equipment, where the power supplies must also be carried, such as hearing aid apparatus or radio equipment carried in test apparatus. In such applications where space itself is at a premium the lower requirements of exceedingly small devices allow the power supplies in turn to be smaller and to be designed to occupy less space.

Exceedingly small or minute devices may also be employed as amplifiers in repeaters or recorders in cable applications where low power consumption and the other characteristics discussed above are advantageous and where the inexpensiveness of the component parts is of great importance because of the large number employed in the repeaters spaced at close intervals along the cable.

Difficulty has been encountered in prior small electron discharge devices in joining the tiny electrodes to the leads as the application of the necessary amount of heat for a soldering, welding, or brazing operation results in distortion and deformation of the very fine electrodes. The application of heat to these elements would destroy the degree of dimensional control required in these small structures. Moreover, mechanical connections and supports between the leads and the electrodes unduly complicate the structure, thereby greatly increasing the difficulty and cost of assembling, and further considerably enlarge the structure, preventing the attainment of a minimum occupation of space by the complete device.

One object of this invention is to realize a marked reduction in the size of electron discharge devices. More specifically, one object of this invention is to provide an electron discharge device which may be contained in a sphere having a radius of the order of 0.03 inch or less.

Another object of this invention is to enable and facilitate the fabrication of such devices.

A further object of this invention is to simplify and expedite the construction of electrodes

2

for electron discharge devices and, more specifically, of electrodes for minute devices.

Still another object of this invention is to increase the rigidity and maintain the cooperative relation of exceedingly small electrodes for electron discharge devices.

In one illustrative embodiment of this invention, a triode comprises four ductile metal leads. One lead is flattened at its end and bent over to form the anode. A second lead has one end formed into a ring, flattened, and bent over to form the control electrode. The other two leads support a fine wire filament bumped or otherwise forced into their ends and having a sphere of emitting material supported thereon projecting into the center of the control electrode ring. The leads are supported directly in a glass base and the electrode unit is encompassed by an enclosing vessel.

An appreciation of the minuteness of an electron discharge device constructed in accordance with this invention can be gained by considering that the outer diameter of the enclosing vessel may be of the order of one-sixteenth of an inch or less. This is less than one-half the width of a paper match or about the thickness of a five-cent piece. A rough comparison in size between minute electron discharge devices in accordance with this invention and other devices can be had by considering the difference in size between the diameter of the face of the five-cent piece and its thickness.

In accordance with one feature of this invention, the grid and control electrode are fabricated integral with their leads and the cathode is a fine wire filament bumped, or otherwise pressed, into the ends of two other leads, whereby the over-all size of the electrode unit is reduced to a minimum. Specifically, in accordance with this feature, the electrode leads extend directly through the base and are positioned parallel to each other, the end of one lead being flattened to define an anode, and the end of another lead being flattened to define a control electrode. Other electrodes, if desired, may be formed in the same manner.

In accordance with another feature of this invention, a control electrode is fabricated by forming the end of the lead wire into an open ring and swaging or otherwise flattening that ring, thereby forming a disc electrode having a central aperture. Good electron control in a minute electron discharge device is attained by such an electrode, the emitting surface being either adja-

cent to or extending into the aperture in the control disc.

In accordance with still another feature of this invention, the very fine filament wire employed in a minute electron discharge device is secured to and supported from two lead wires without the application of heat, the ends of the filament being laterally bumped or otherwise pressed into the lateral ends of the leads. By forcing a length of the end of the filament into the side of the lead end, the lead being of a ductile and softer material, sufficient support is attained for the filament to rigidly position it in proper relation to the anode and other electrodes in the minute electron discharge device.

In accordance with still another feature of this invention, the electrode leads are dropped into apertures in a jig or fixture which positions them in relation to each other. The jig is provided with a depression in its face into which powdered glass is put, the glass filling the depression and surrounding the leads. After an enclosing vessel or bulb is placed on the powdered glass encompassing the electrode unit, the jig together with the other elements is removed to an evacuating station. In accordance with this feature, the vessel is evacuated through the porous powdered glass. Following evacuation the electrodes are processed and the powdered glass then melted accomplishing simultaneously a sealing in of the leads and the bulb, a sealing off of the evacuated vessel, and a fusion and formation of the base.

A complete understanding of this invention and of the various features thereof may be gained from consideration of the following detailed description and the accompanying drawing, in which:

Fig. 1 is a perspective view of an electron discharge device illustrating one embodiment of this invention, a portion of the glass envelope having been broken away to show the internal elements of the device and the device being shown as a triode for purposes of illustration;

Fig. 2 is a plan view of the device of Fig. 1 along the line 2—2;

Fig. 3 is a sectional view of the device of Fig. 1 along the line 3—3 of Fig. 2, the device being shown mounted in a jig prior to the pumping and sealing operations;

Fig. 4 is another sectional view of the device of Fig. 1 along the line 4—4 of Fig. 2;

Fig. 5 is a perspective view of a bell jar pumping arrangement that may be employed in the processing of devices in accordance with this invention; and

Fig. 6 is a perspective view of a support assembly that may be employed to position the device in the arrangement of Fig. 5, portions of the jig, device, heating coil and insulating lead sheath having been broken away.

Referring now to the drawing, the electron discharge device of Fig. 1 comprises a bulb 10, which is shown as made of glass, but may be of metal, ceramic, or other material known to the art for use as an enclosing vessel. The bulb 10 is directly sealed to a base 11 which is of glass or other suitable fusible insulating material. Leads 12, 13, 14 and 15 extend through the base 11 and are sealed directly thereto, in a manner to be described below. The leads are formed of a ductile material suitable for the forming operations, such as nickel, though other ductile conducting materials may be employed as is known in the art.

The cathode comprises a filament loop 17, the ends of which are laterally pressed or bumped into the leads 14 and 15 adjacent the ends thereof, and a sphere or globule 18 of emitting material carried by the loop 17 at its apex, as best seen in Fig. 3. The control electrode comprises an apertured disc or flattened ring 19 which is formed integral with the lead 13, the ring being open and having a central aperture 20. The cathode globule 18 is positioned in the aperture 20 and extends approximately to the upper side of the flattened ring 19. The anode comprises the flattened end 22 of the lead 12, which is formed integral with that lead and bent over at right angles to it. The anode 22 is positioned directly adjacent the control electrode 19 and opposite the cathode 18.

While the electron discharge device described above and illustrated in the drawings is a triode it is to be understood that the representation as a triode is merely illustrative and that the concept and principles of this invention apply equally to other devices comprising a different number of electrodes. Thus the lead 13 and control electrode 19 may be omitted to provide a diode or conversely another and similar control electrode may be interposed between the electrode 19 and the anode 22 to provide a tetrode.

The assembling of the device may advantageously be accomplished in a jig and a support assembly, shown in Figs. 3 and 6, which retain the parts in their proper dimensional relation through to completion of the device. The jig 24, which may advantageously be of oxidized stainless steel, is a cylindrical block having two concentric depressions 25 and 26, depression 25 being in the lower face and depression 26 in the upper face. A plurality of apertures extend through the jig 24 between the two depressions 25 and 26, the apertures being arranged to allow passage therethrough of the leads 12, 13, 14 and 15, only two apertures 28 and 29 for leads 14 and 15 being perceivable in Fig. 3. The apertures are larger than the leads so that the leads do not contact the jig. An insulating lead sheath 31, best seen in Fig. 6 and which will be more fully discussed below, extends into the lower depression 25 in the jig 24 and has apertures positioned adjacent the apertures in the jig. The leads 12, 13, 14 and 15 closely fit into the apertures in the insulating sheath 31, only apertures 32 and 33 for leads 14 and 15 being shown in Fig. 3.

In fabricating the device, the anode and control electrode are advantageously first formed integral with their leads. Thus, the anode is formed by swaging or flattening the end 22 of the lead 12 and bending it to a position at right angles to the remainder of the lead. Similarly the control electrode is formed by forming the end 19 of the lead 13 into a ring, swaging or flattening the ring and then bending it to a position at right angles to the remainder of the lead.

In assembling the device, the cathode leads 14 and 15 are first placed in the apertures 28 and 29 in the jig 24 and into the apertures 32 and 33 in the insulating lead sheath 31. The height of the leads is determined by their lengths as the leads rest on an insulating lead stop 35 at the base of the sheath 31, as best seen in Fig. 6. The V-shaped filament loop 17 is then positioned between the two leads 14 and 15 by means of a V-shaped mandrel of a hard material, such as a hardened steel, and the leads pressed or bumped

5

against the mandrel to force the filament loop into the ends of the ductile leads. A quantity of emitting material is then transferred to the apex of the filament loop 17, as is known in the art, to form the globule 18.

The preformed control electrode and anode are positioned in proper relation to the emitter and to each other by placing the leads 12 and 13 into appropriate apertures in the jig 24 and sheath 31, the spacing between the various electrodes being controlled by the length of the leads as discussed above. Rotation of the leads may be prevented by set screws 36, only one of which is shown in Fig. 3 bearing against lead 14. As seen in Fig. 3 with reference to lead 14 the screw 36 extends through a threaded aperture 37 in the jig 24 and through an aperture 38 in the sheath 31. An insulating washer 39 attached to the end of the screw 36 insulates it from the lead, thereby preventing the shorting of all the leads through the jig 24 during the processing described below.

While the electrode leads are illustrated as being circular in cross section it is apparent that any shape of longitudinal cross section may be advantageously employed. Thus the lead may be of asymmetrical cross section to mate with a similarly shaped aperture in the sheath 31 to prevent rotation of the lead in the jig during processing, though rotation may be prevented in other known ways, as by set screws 36 extending through the sides of the jig and sheath into the apertures to hold the leads in their proper positions as shown.

When the leads have been properly mounted in position in the jig 24, a low temperature powdered glass 41 is sifted into the depression 26 in the face of the jig 24 until the leads are surrounded and the depression is completely filled. The bulb 10 is then placed in position on top of the powdered glass 41, and the combination including the jig, the electrodes held in position in the jig, the powdered glass, the bulb and the tube support assembly transferred into a bell jar pumping set-up, as shown in Fig. 5.

Referring now to that figure, the support assembly is screwed into position on the pump plate 42 by the screw member 43 secured to an insulating block 44 that forms the base of the support assembly. The insulating sheath is supported from the insulating block 44 by a metal stud 45, the leads being insulated therefrom by the insulating lead stop 35. The insulating lead sheath 31 is further supported by contact springs 46, which will be described further below. A bell jar 48 rests on a gasket 47 on the pump plate 42 and encompasses the support assembly. The bell jar 48 is evacuated through a pump port 49 in the pump plate 42 connected to a vacuum pump by a tubing 50, as is well known in the art. The interior of the electron discharge device is evacuated at the same time as the evacuation of the bell jar 48, the device being evacuated through the porous glass stem section 51 exterior to the bulb 10 and which is best seen in Fig. 3.

During the evacuation of the device and the bell jar 48 to a high vacuum the device is baked to outgas the electrodes. A radiant heating coil 52 may advantageously be employed for this purpose, the heating coil being supported by a heating coil support 53 secured to the pump plate 42. The support 53 is advantageously hinged, as at 54, to allow the coil 53 to be positioned facily around the electron discharge device after the support assembly has been screwed into the base plate 42. Leads 55 and 56 for the heating coil 52

6

extend through insulated seals 57 in the pump plate 42 and are attached to an appropriate heating coil power supply. The radiant heating coil 52 heats the jig 24 and the electrodes and leads to approximately 400° C. to remove the occluded gases without causing fusion of the powdered glass 28. These gases are removed from the device and expelled from the bell jar 48 by the vacuum pump which continues to evacuate the bell jar during this process.

After this baking process the heating coil 52 is disconnected from its power supply and the electrodes allowed to cool. The cathode is then activated. Referring now especially to Fig. 6, the insulating sheath 31 has a plurality of cut-out portions 59 in its sides, one for each lead aperture extending through the sheath. These cut-out portions 59 are deep enough to intercept those lead apertures and thus expose a length of the lead. A contact spring 46 bears against each of the leads, thereby both aiding to support the assembly and making contact with the lead and therefore the electrode. The contact springs 46 are secured to the insulating block 44 as by screws 60. Each spring 46 has attached thereto adjacent the screw 60 a lead wire, such as the wires 61, 62, 63 and 64, which extends through the pump plate 42 by means of insulated seals 57. Activation of the cathode occurs by passing current through the wires 62 and 64 to which are electrically connected the leads 14 and 15.

Following activation of the cathode 18, the control electrode 19 and the anode 22 are each further processed by electronic bombardment by passing a current through each and the cathode individually. It is understood of course that in other embodiments of this invention comprising different numbers of electrodes, additional appropriate springs 46 and wires are provided in the pumping station and that these other electrodes are processed similarly to the method being described for this illustrative embodiment.

Seal in of the leads 12, 13, 14 and 15 in the stem, sealing of the bulb 10 to the stem, seal off of the evacuated vessel, and the formation of the stem 11 itself may then be advantageously simultaneously accomplished by heating the powdered glass 41 to a sufficiently high temperature to melt the low temperature glass and cause a fusion of the glass to the leads and bulb and its own solidification. The heat is supplied by the radiant heating coil 52 which raises the temperature of the jig 24 to fuse the powdered glass, the temperature being raised above that of the baking process. This fusion of the powdered glass simultaneously forms the base or stem, seals the leads in place, and seals off the device by sealing the base 11 to the bulb 10.

While the processing of an electron discharge device in accordance with this invention in a bell jar pumping arrangement has been described in which a single device is processed in the pumping station, it is of course to be understood that in commercial practice a large number of these minute devices would be mounted, evacuated, and processed at the same time in one station. Thus each device would be evacuated through the porous glass base at the same time as the evacuation of the bell jar and the processing of the electrodes could advantageously occur simultaneously by connecting the individual contact springs for similar electrodes in series.

The materials of the base 11, bulb 10, and leads 12, 13, 14 and 15 should be chosen so that their thermal characteristics match each other to pro-

vide proper seals in this operation. Thus the base may be of a low temperature powdered sealing glass known commercially as Corning No. 7570, the leads of nickel or a nickel alloy, and the bulb of a lead glass or a Kovar shell.

An appreciation of the size of a minute electron discharge device constructed in accordance with this invention and of its characteristics can be gained from consideration of the physical dimensions and electrical characteristics of the illustrative embodiment depicted in the drawing and described above, it being apparent that these values will vary with other embodiments constructed in accordance with the invention, such as, for example, a diode or a tetrode. Physically the height of the device, which is the maximum external dimension, exclusive of lead length is about one-sixteenth of an inch. The bulb is about .060 inch in diameter and the base 11 in the embodiment illustrated has an initial diameter of about .062 inch. The leads 12, 13, 14 and 15 may be each .005 inch in diameter. The anode 22 and control disc or ring 19 are about .002 inch thick and the aperture 20 in the control electrode disc or ring 19 has a diameter of from .001 inch to .002 inch. The filament 17 may advantageously be of tungsten .0003 inch in diameter, such fine wire being commercially available. These dimensions, and particularly the external diameters, may easily be slightly reduced if desired to further decrease the over-all size of the device.

The filament voltage required may be about .04 volt and the filament current about .015 ampere, giving a filament power consumption of the order of one-half a milliwatt. It is to be understood that the conducting diameter of the filament may be decreased by known methods without lessening the mechanical stability so that different filament voltages may be employed without altering the input power required. The device may be operated as an oscillator or an amplifier in the same manner as conventional electron discharge devices. It may advantageously operate with a control electrode at ground potential, an anode voltage of two volts, and an anode current of two microamperes.

It is apparent therefore that such a device is capable of employment where an exceedingly small sized device is required, as the whole structure can occupy the space of a sphere of about a .03 inch radius or less and that such a device requires exceedingly low voltage and power supplies. A control electrode integral with its lead comprising a disc having a central aperture, in which the emitter is located, as described above, achieves control action equivalent to the conventional helical grids, while having the advantages of mechanical simplicity, minuteness of size both for itself and its support, close spacings between it and the other electrodes, and allowing the employment of very low anode voltages, thereby reducing the size of the concomitant equipment required by the minute electron discharge device.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. An electron discharge device comprising an anode solid rod lead, a flat anode surface integral with said lead, a control electrode solid rod lead, a flat control electrode having an aperture therein

and being integral with said control electrode lead, and a cathode adjacent said aperture.

2. An electrode assembly for an electron discharge device comprising an anode solid rod lead, an anode surface integral with said lead and bent at an angle thereto, a control electrode solid rod lead, a flat control electrode integral with said control electrode lead and having an aperture therein, said electrode being adjacent said anode surface and substantially parallel thereto, and a cathode positioned in said aperture.

3. An electron discharge device comprising a plurality of parallel lead-in wires, an anode integral with one of said wires, a flat control electrode integral with another of said wires and having an aperture therein, and a V-shaped cathode filament supported by other of said wires and having an emitting surface at the apex extending into said aperture.

4. An electrode assembly for an electron discharge device comprising a plurality of lead-in wires, the internal end of one of said wires being flat and defining an anode, the internal end of another of said wires being a flat disc defining a control electrode, said disc having an aperture therein, the internal ends of two of said wires supporting a V-shaped filament, the ends of said filament extending laterally into the ends of said two wires, and a globule of emitting material supported at the apex of said V and extending into said aperture.

5. A minute electron discharge device comprising a plurality of lead-in wires sealed directly in the base of said device, an anode integral with one of said wires, a flat control electrode integral with another of said wires and having an aperture therein, said control electrode disc and said anode extending substantially parallel and adjacent each other, a cathode filament having its ends extending laterally into the lateral ends of two other of said wires, and a globule of emitting material supported by said filament and extending into said aperture opposite said anode, said device fitting into the volume defined by a sphere of a radius of .03 inch or less.

6. A minute electron discharge device comprising a vessel, an insulating base sealed to said vessel, a plurality of lead-in wires sealed directly in said base, the end of one of said wires being flat and defining an anode, the end of at least one other electrode being a flat disc having an aperture therein defining an electrode, a V-shaped cathode filament having its ends extending laterally into the lateral ends of two other of said wires, and a globule of emitting material supported at the apex of said V-shaped filament and extending into said aperture opposite said anode, said device fitting into a volume defined by a sphere of a radius of .03 inch or less.

7. An electrode assembly for an electron discharge device comprising a plurality of wires, the end of one of said wires being flat and defining an anode, the end of at least another of said wires being a flat disc having an aperture therein defining an electrode, a V-shaped cathode filament having its ends extending laterally into the lateral ends of two other of said wires, and a globule of emitting material supported at the apex of said V-shaped filament and extending into said aperture opposite said anode.

8. A minute electron discharge device comprising a vessel, an insulating base sealed to said vessel, a plurality of lead-in wires extending through said base and sealed thereto, a flat anode surface formed integral with one of said leads, said anode

surface being bent at an angle to said one lead, a V-shaped cathode filament having its ends extending laterally into the lateral ends of two other of said leads, and a globule of emitting material supported by said filament opposite said anode surface, said device fitting into a volume defined by a sphere of a radius of .03 inch or less.

9. A minute electron discharge device comprising a plurality of lead-in wires, an anode, an electrode comprising a flat ring integral with one of said wires and having an aperture therein, said electrode being adjacent said anode, and a filamentary loop cathode having the apex thereof extending into said aperture opposite said anode.

LUTHER E. CISNE.

15

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
2,076,671	Richter et al.	Apr. 13, 1937
2,260,264	Scharfnagel	Oct. 21, 1941
2,353,743	McArthur	July 18, 1944
2,423,819	Chevigny	July 8, 1947
2,428,610	Beggs	Oct. 7, 1947
2,451,517	Smith	Oct. 19, 1948
2,459,277	Halstead et al.	Jan. 18, 1949
2,491,995	McIntosh et al.	Dec. 20, 1949
2,493,555	Simpson	Jan. 3, 1950
2,500,355	Haas	Mar. 14, 1950