March 29, 1955 M. B. SHRADER 2,705,294

ELECTRON DISCHARGE DEVICE

Filed March 13, 1952 3 Sheets-Sheet 1

Fig. 4.

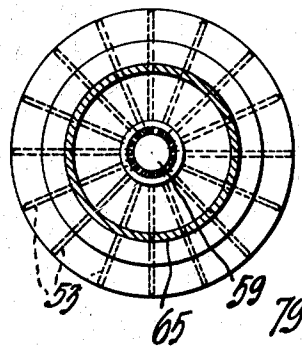
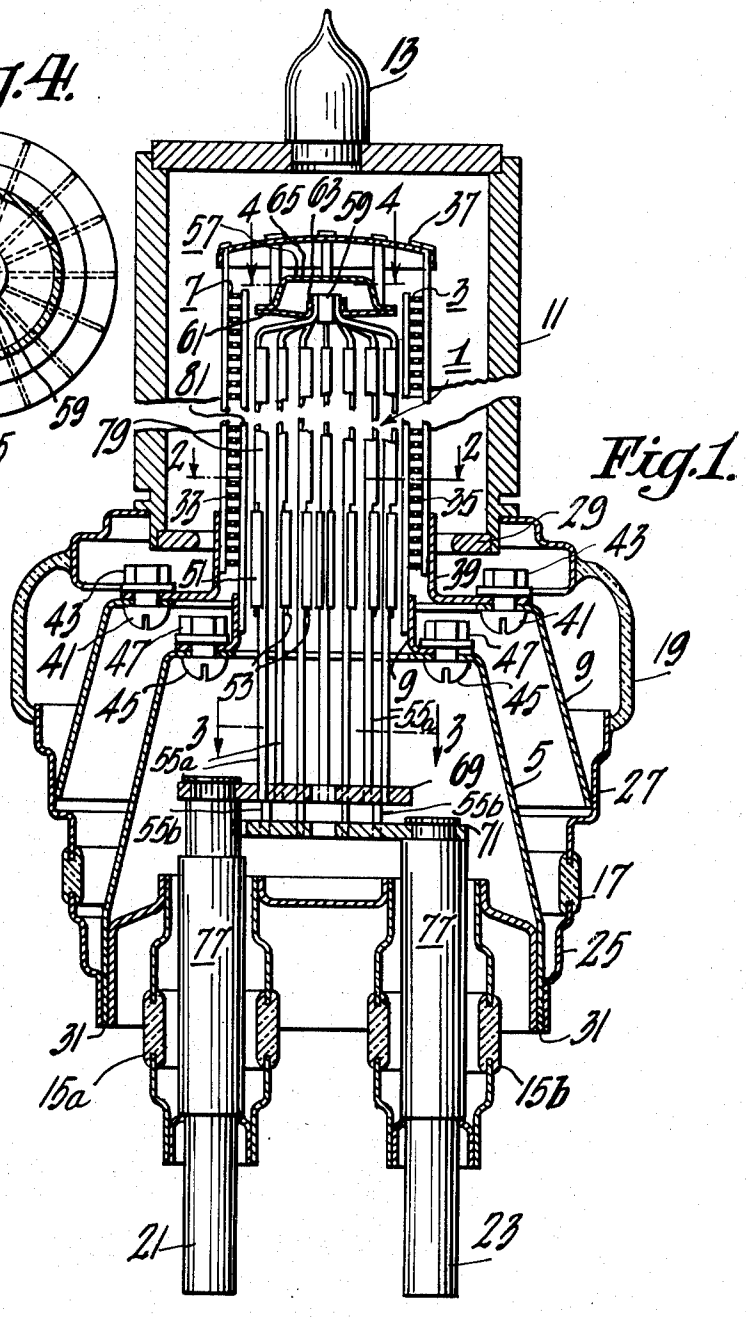


Fig. 1.



INVENTOR
Merrald B. Schrader
BY
William A. Zalesak
ATTORNEY

March 29, 1955 M. B. SHRADER 2,705,294

ELECTRON DISCHARGE DEVICE

Filed March 13, 1952 3 Sheets-Sheet 2

Fig. 2.

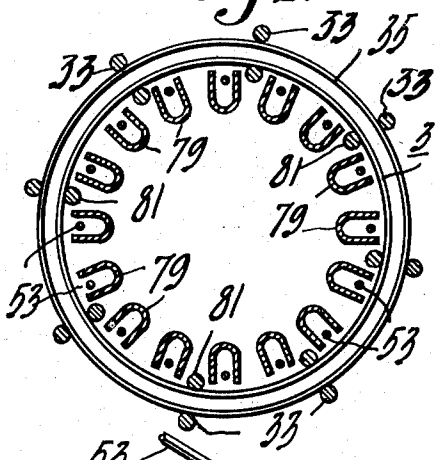


Fig. 3.

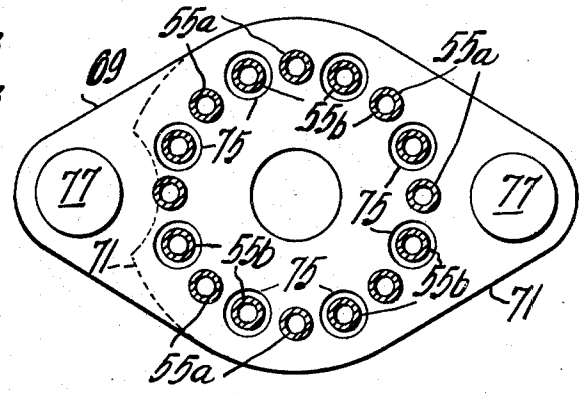


Fig. 6.

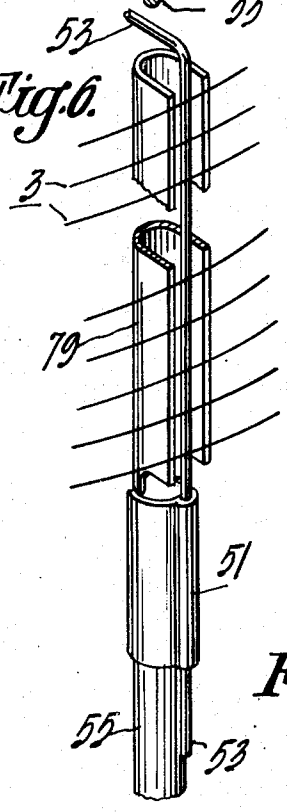


Fig. 9.



Fig. 10.



Fig. 7.

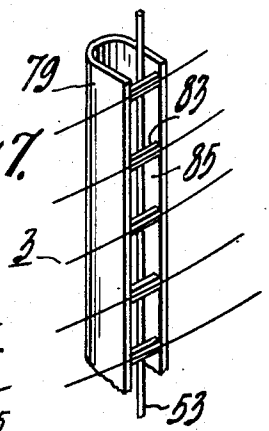
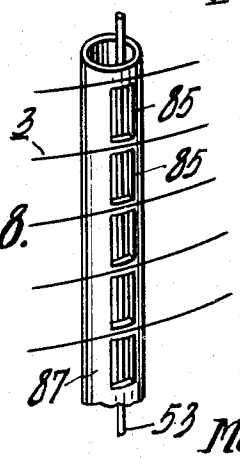


Fig. 8.



INVENTOR
Merrald B. Schrader
BY
William A. Zaleski
ATTORNEY

March 29, 1955 M. B. SHRADER 2,705,294

ELECTRON DISCHARGE DEVICE

Filed March 13, 1952 3 Sheets-Sheet 3

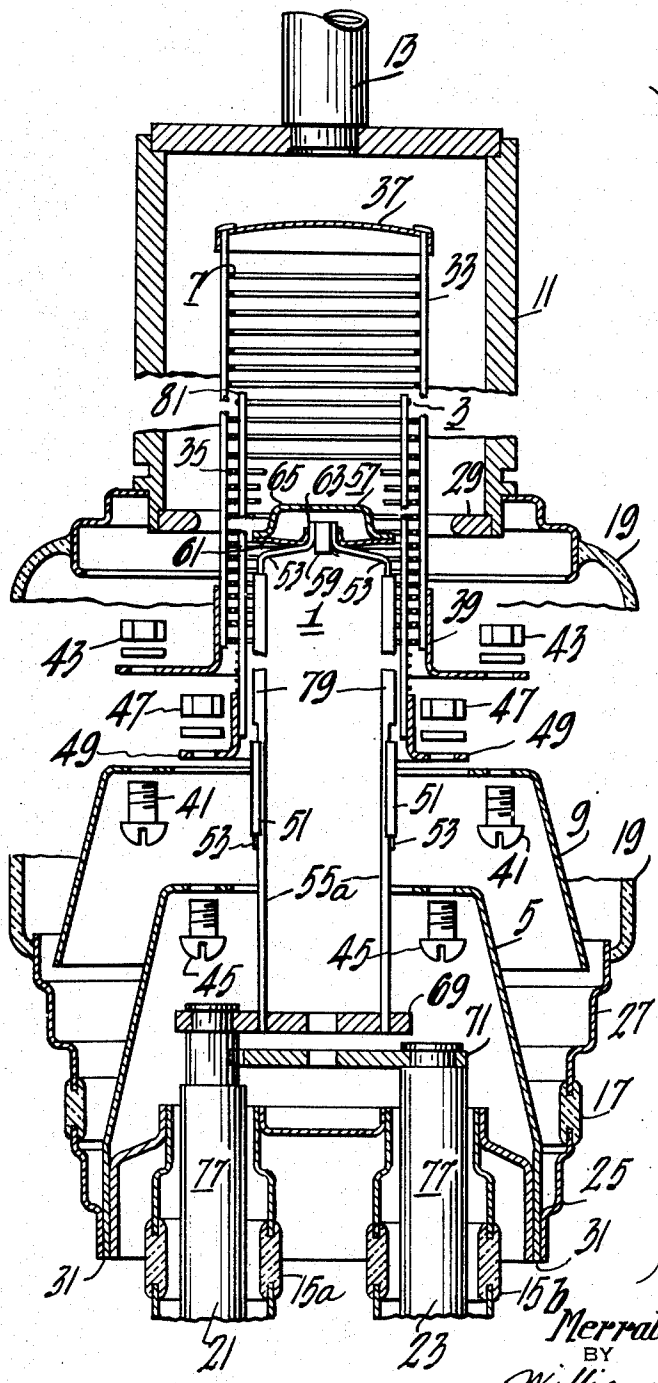


Fig. 5.

INVENTOR
Merrald B. Schrader
BY
William A. Zalesak
ATTORNEY

United States Patent Office 2,705,294
Patented Mar. 29, 1955

2,705,294

ELECTRON DISCHARGE DEVICE

Merrald B. Shrader, Mount Joy, Pa., assignor to Radio Corporation of America, a corporation of Delaware

Application March 13, 1952, Serial No. 276,351

8 Claims. (Cl. 313—240)

This invention relates to electron discharge devices and particularly to power tubes which are designed to operate at very high frequencies.

The problem of cooling the envelope and electrodes of power tubes has long been present, since overheating caused by electron bombardment or thermal radiation from the cathode are factors which limit the amount of power which may be applied to a particular tube.

The electrode most subject to electron bombardment is the tube anode, but, since the anode may be manufactured as a part of the tube envelope, external means such as forced air or water may be used to cool it, as is well known under prior art practice. Other electrodes, such as the grid or grids, however, are usually supported by members which are able to conduct only a limited amount of heat from the tube. Also, since heat may weaken the tube envelope, especially those portions of the envelope which are adjacent metal-to-ceramic or metal-to-glass seals, some means must be provided to shield these envelope areas from electron bombardment or thermal radiation, or both.

In power tubes which are designed to operate at frequencies of the order of a few megacycles overheating of the envelope and electrodes is controlled to some extent by providing relatively large spacing between electrodes, thus permitting the use of large electrode supporting structures which can withstand considerable heating. Also, in such low frequency power tubes it has been the practice to protect the tube envelope from overheating by extending the length of the anode beyond the active area of the cathode so that the anode serves as a shield for the envelope.

However, in power tubes designed for use at very high frequencies, this method of shielding is unsatisfactory because of the large stray capacities resulting from the extra anode length which has been added for shielding purposes. Also, it is necessary, with V. H. F. (very high frequency) tubes, to keep all lengths of the active electrodes at a minimum, since the physical dimensions of the tube should be small in comparison to the operating wavelength.

A second means of protecting the tube envelope from bulb bombardment and thermal radiation involves use of a flat dish type shield which is usually mounted on either the control grid or screen grid supporting structure, facing the anode and in some cases overlapping the open end of the anode.

A shield of this type has the advantage of making possible short compact tube construction, but has a serious disadvantage in that the shield becomes heated by the bombarding electrons and the thermal radiation from the cathode. Since the shield is mounted on the supporting structure for one of the grids, the heat from the shield further complicates the already difficult problem of cooling the grid mount.

Returning to the problem of prevention of overheating of the tube electrodes, I have found that, in some power tubes having self-supporting cage type filaments, there is a steady flow of electrons between the top of the filament and the anode (or the screen grid top cap in event the tube is a tetrode). This flow of electrons is sometimes great enough so that it becomes impossible to cut off the flow regardless of the bias voltage applied to the control grid. Such currents may be and often are of sufficient magnitude to burn a hole in the top cap. A prior art solution to the problem involved use of a cap or a configuration of cross wires on the top of the control

grid in order to stop the flow of electrons to the other electrodes, but, as in the case of the dish-shaped shield used to prevent overheating of the tube envelope, such a cap or cross wire arrangement resulted in larger grid energy absorption, and further aggravated the problem of grid heating.

Although the flow of electrons from the top of the filament is a factor which contributes to overheating of the tube electrodes, the greatest amount of heating of the grids may be attributed to electrons which are absorbed by the grid turns and support members. Since the grid support members for power tubes designed to operate at V. H. F. must be relatively small because of the desired close electrode spacing, there has been considerable progress under prior art practice towards lowering grid power absorption as a means for combatting overheating of the grid structures. For instance, the turns and side support rods of control and screen grids have been aligned in order to reduce screen grid current. However, I have determined that the area of the side support rods for the control grid and screen grid may be as much as half that of the total active grid area, and therefore up to half the grid current may be absorbed by the side support rods. This fact, too, has been recognized in the prior art, and beam former structures have been incorporated in tubes of special design for the purpose of beaming the electrons through the spaces between the grid turns or supporting structure, or both. These beam formers, however, have been rather expensive to manufacture and have seen little or no use in tubes of more or less conventional design in which the tube cathode is a multistrand cage type filament. From the foregoing, it is apparent that a simple beam former structure adaptable to use with conventional types of power tubes would be advantageous in reducing grid current absorption and thus reduce grid heating.

The principal object of my invention is to provide an improved power tube capable of operation and of high power output at very high frequencies.

Another object of my invention is to provide a power tube capable of operation at very high frequencies and having improved means for protecting the tube envelope and electrodes from the danger of overheating because of electron bombardment or thermal radiation.

A further object of my invention is to provide an improved shield for protecting the tube envelope from bulb bombardment and thermal radiation.

Still another object of my invention is to provide an improved top shield arrangement for a power tube cathode.

A still further object of my invention is to provide beam forming action for the individual strands of a cage type self-supporting filament structure in a power tube.

In carrying out the above objects of my invention, I make use of some or all of the improvements in power tube construction which are set forth below.

One novel feature of my invention is an anode shield comprising a flat circular ring mounted on the inside diameter of the anode. Such a shield protects the tube envelope from bulb bombardment and thermal radiation, yet permits use of the short electrode leads which are essential to V. H. F. circuitry. Moreover, my novel shield is readily cooled, since it is attached directly to the tube anode, which may be cooled in several ways as mentioned above.

Another novel feature of my invention is a filament cap or top shield comprising a two piece molybdenum shield, one piece being a slightly concave disc having a center extruded hole which is placed over the junction of the filament strands and welded thereto, while the second piece, a "hat shaped" shield, is placed over the first piece and spot welded to the first piece at several points around their edges. I have found that my improved filament shield eliminates emission from the top of the multistrand cage type filament and possesses other advantages which will be explained later.

Still another novel feature of my invention is the provision of a channel beam former behind each strand of the self-supporting cage type filament. By means of the beam former channels, electrons are beamed around side

support rods or grid turns, or both, thus considerably reducing the amount of power absorbed by the grid structure. Less power absorption results in less heating of the grids, thus allowing more power input to the tube, other factors permitting. The beam channels are maintained at filament potential and in function are similar to the beam formers described and claimed in U. S. Patent No. 2,544,664, issued March 13, 1951, to L. P. Garner, William N. Parker, and W. E. Harbaugh, and assigned to the same assignee as this application. However, my beam formers may be applied to power tubes of conventional construction with but slight modification of the tube structure, with very little additional cost, and without adversely affecting the operating characteristics of the tube.

The novel features which I consider to be characteristic of my invention are set forth with particularity in the appended claims. The invention itself will best be understood by reference to the following description taken in connection with the accompanying drawings, in which:

Fig. 1 is a view of a power tube made embodying my invention;

Fig. 2 is a section taken on the line **2—2** of Fig. 1;

Fig. 3 is a section taken on the line **3—3** of Fig. 1;

Fig. 4 is a section taken on the line **4—4** of Fig. 1;

Fig. 5 is an exploded view of the tube of Fig. 1;

Fig. 6 is a view in perspective of one of the channel-like "beam formers" for a filament of the tube;

Figs. 7 and 8 are fragmentary views in perspective of other types of "beam formers";

Fig. 9 is a cross-section of a clamp used to connect a filament strand to the beam channel of Figs. 6, 7, or 8; and

Fig. 10 is a view similar to Fig. 9 but with the view of a clamp attached to a solid filament support rod.

Referring to Figure 1, there is shown a tetrode power tube comprising, in an evacuated envelope, a cathode **1**, shown as a cage type multistrand filament, a control grid **3** mounted on a truncated conical support structure **5**, a screen grid **7** mounted on a truncated conical support structure **9**, and an anode **11** having an exhaust tubulation **13**. The vitreous portions of the envelope, or bulb, **15***a*, **15***b*, **17**, and **19** provide insulation between the filament terminals **21**, **23**, the metal bands **25**, **27**, which serve as terminals for control grid **3**, and screen grid **7**, respectively. The conical control and screen grid support structures, **5** and **9**, are electrically connected to bulb terminals **25** and **27**, respectively. The control grid support structure **5**, filament mount assembly **77** and envelope grid terminal portion **25** are joined at **31**.

Referring to the construction of the cathode **1**, it may be seen that the filament support structure comprises an upper and lower support member **69**, **71**, and sixteen circularly arranged individual support elements **55***a*, **55***b*. The upper and lower support members, **69**, **71** are each connected to one of the external filament terminals **21** and **23**.

The support elements comprise eight shorter and eight longer elements **55***a*, **55***b*. The longer elements, **55***b*, are attached to the lower support member **71**, with individual elements extending through apertures **75** (shown in Fig. 3) in the upper support member **69**, and positioned between the adjacent pairs of the eight longer elements as shown in Figure 3.

Individual filament strands **53** are attached to said support elements **55***a*, **55***b* by means of clamps **51** which are mechanically pinched on during tube assembly, but which are sintered to the filament strand **53** and its support element **55***a*, **55***b* during tube processing. The tops of the filament strands **53** are bent inwardly, fastened to a core plug **59**, and the ends and the core plug are then arc welded to make good electrical and mechanical contact at the junction **63** thereof.

It can be seen in Figure 1 that the control grid and screen grid support **5**, **9**, in addition to performing their support functions, also shield the portion of the tube envelope below the screen grid terminal **27** from bulb bombardment and direct thermal radiation from the cathode. However, in order to shield the vitreous portion **19** between the anode **11** and screen grid terminal **27**, I have provided an inwardly extending flat circular ring **29** mounted on the inside diameter of the anode. This anode shield ring **29** serves to partially close in the open end of the anode **11**, and therefore prevents high velocity electrons from escaping and causing breakdown of the adjacent vitreous part associated with the vacuum envelope. The ring **29** also prevents the radiant energy in the hot filament from striking the said adjacent vitreous seal (**19**) area.

The anode **11** and ring **29** may be of one piece construction, but I prefer, for reasons of cost and ease of construction, to prepare the parts separately and then braze them together. Since the ring of **29** is brazed to the anode **11**, it can be easily cooled by conduction to the heavy (either water or air cooled, but not previously illustrated as either) anode **11**. With such a construction, short compact tubes can be built which don't overheat the grid support, and in which stray capacity may be held to a minimum.

Another important feature of my invention has to do with the ease with which repairs may be made in event an electrode of the tube is damaged during assembly, or while the tube is being processed. In the past, salvaging or repairing of the filament structure **1** was accomplished by cutting the weld area **31** open, or by cracking the seals **17**, **19**, and completely rebuilding the tube. Cutting open the weld is a dangerous operation and often results in a damaged filament or grid. According to my novel electrode mounting arrangement, no weld need be disturbed, and the filament **1**, or the grids **3**, **7**, may be repaired at any time prior to the sealing on of the anode **11** without cutting any seals. Even after the anode has been sealed on, the opening of the tube involves only a simple cut in one insulator or section, as will be explained below.

Referring to Figure 5, it can be seen that the screen grid **7**, comprising side support rods **33**, winding **35**, top cap **37**, and flange **39**, may be removed from the screen grid support structure **9**, by removing the several bolts **41** and nuts **43**, which fasten flange **39** to the support structure **9**.

Once the screen grid **7** is removed, the control grid **3** may be removed by removing the bolts **45** and nuts **47** which fasten the control grid mounting flange **49** to the control grid support structure **5**. Thus, defective grids may easily be replaced by usable units. Also, the filament mount assembly is exposed so that the filament may be rebuilt, since the clamp **51**, attaching the filament strands **53** to the support cylinders **55**, is merely sintered to the strand and cylinder rather than being welded thereto. The clamp **51** can usually be loosed by merely tapping it with a light, sharp blow.

Should the tube prove defective during processing, the tube envelope may easily be opened by making a cut through the vitreous insulator **19** between screen grid terminal **27** and anode **11**. The insulator being cut open, the anode may be lifted off and the tube may be disassembled as described above. When the repairs have been made, a new anode exhaust tubulation (not shown) is mounted on the anode **11**, and the anode section is "reglassed" and sealed to the rest of the tube by a glass-to-glass or ceramic-to-ceramic seal (of insulator **19** which was cut open) depending upon which type insulator is used. The tube may then be processed according to the usual schedules.

Another feature of my invention concerns a novel top-shield **57** which is attached to the top of the filament cage. In a self-supporting cage-type filament, such as is illustrated in Figure 1, the ends of the strands **1** of the filament are brought together at the top of the filament, either fastened around a core plug **59**, or merely bunched together, and then the ends are welded together, along with the core plug, if any, to become a solid mass. Unfortunately, the top portion of the filament serves as a source of electron emission which causes increased grid current, or overheating of the grid structure, or both. Although flat shields have previously been welded to the top of the filament cage, I have found that this type of shield, while it does reduce the emission current considerably, is not completely satisfactory. For instance, the center weld area usually continues to emit electrons toward the grid structures when this type of shield is used. To eliminate the emission towards the grid structures or the anode, I provide a two-piece molybdenum shield placed over the top portion of the shield. The shield consists of a slightly concave disc **61** having a center extruded hole which is placed over the junction **63** of the filament strand and attached, by arc welding, for

example, to the filament strand junction. Over the concave disc a "hat" shaped molybdenum shield **65** is placed and spot-welded around the outer ends at several points. The "hat" section **65** prevents emission being drawn from the filament strand junction. An additional advantage of such a shield arrangement is that "hat" forms an oven which heats the molybdenum disc **61** and the wire (not shown) which is wrapped around the junction of the filament strand, causing sufficient melting to insure a uniform molybdenum brazed joint in addition to the arc weld. This molybdenum brazed joint further insures good electrical and mechanical contact at the junction. The degree of melting may be controlled by proper adjustment of the filament flashing temperature during tube processing. The further advantage of the top shield is that it shields the top portion of the filament while the filament is being carburized. In the past, the majority of filament failures have occurred at the top bent portion of the filament strands. By shielding the bent portions of the filament during carburization, embrittling of these portions caused by carburization is avoided, and a stronger filament structure results.

In accordance with another feature of my invention, a channel beam former **79** is positioned behind each filament strand. The beam former **79** causes the emission from the filament strands **53** to flow in beams, thereby reducing electron current to the control grid and screen grid support rods **81, 33**. The "beam channels" are maintained at filament potential, since the lower end of each channel is electrically connected to (or is a part of) a filament support element.

In the embodiment shown in Figure 6, the beam channel is constructed from a single piece of molybdenum tubing with the top portion cut along its axis and formed into a channel having a U shape. The bottom portion serves as a support element **55** for the filament strand. The filament strand **53** is attached to the support element **55** by a clamp **51**. Alternatively, a solid molybdenum rod (not shown) may be used as a support element, and the beam channel fastened thereto. As mentioned previously, the filament strands **53** may be mechanically attached to the beam former support element by a clip and then sintered during tube processing as mentioned above, or it may be attached by welding or by any other method which provides good mechanical and electrical contact between strand and support element. A clip **51** suitable for sintering to the strand and its support element is illustrated in Figure 9 in connection with a hollow cylindrical support element, and in Figure 10, in connection with a solid rod cylindrical support element of the type ordinarily used in cage type multistrand filaments.

An additional step toward improving conventional tube characteristics over and above that which I have previously shown, can be accomplished by causing the filament electron current to flow not only in beams along the axis of the beam former, but also transverse to the axis of the beam former. The beam former I have shown thus far, prevents emission to the grid and screen support rods, but not to the individual turns of the grid helix. Prevention (or at least reduction) of emission to the individual grid turns may be accomplished by constructing the combination beam former and support element so that a plurality of slots are formed along the length of the channel. The slots, if aligned with the space between the grid turns, form a barrier over the filament strand directly behind the grid turn. This causes beaming action between grid and screen turns and still further reduces the absorbed grid and screen current. An example of such a structure is shown in Figure 8.

Figure 7 is similar to Figure 6, except that the grid wires are screened from the filament by screening elements **83** which are attached to the open edges of the U-shaped beam former. The spaces between the screening elements constitute the slots **85** through which electrons are beamed. Figure 8 illustrates a channel beam former which comprises a tubular section **87** in which portions between the grid wires had been cut to form slots **85**. With beam channels made according to my invention, conventional tube construction practices can be used to build simple and relatively inexpensive power tubes, but at the same time advantage can be taken of well-known beam forming principles which give greatly improved ratios of control element absorbed current-to-plate current.

What is claimed is:

1. An electrode assembly comprising a self-supporting cage-type cathode comprising a plurality of spaced parallel filament strands in which the individual filament strands are bent inwardly adjacent one end and electrically connected at a common junction, a cathode top shield including an apertured lower member and a hollow hat-shaped upper member secured thereto, at least part of said common junction extending through said apertured member and into the space defined by said hat-shaped member, said cathode top shield being secured to said cathode.

2. An electrode assembly comprising a self-supporting cage-type cathode having a plurality of filament strands in which the individual filament strands are bent inwardly adjacent one end and electrically connected at a common junction, and a cathode top shield including an apertured lower member and a hollow hat-shaped upper member secured thereto, said common junction extending into said aperture in said top shield, said top shield being secured to said cathode adjacent said common junction.

3. An electrode assembly comprising a self-supporting cage-type cathode having a plurality of filament strands, said strands being bent inwardly adjacent one end and electrically connected one to another at a common junction, and a cathode top shield including a disc-like lower member and a hollow hat-shaped upper member secured to said lower member, said lower member being secured to the upper end of said cathode at said junction.

4. An electrode assembly comprising a plurality of filament elements disposed in circumferentially spaced parallel relation about a common axis, individual conductive supports to which said filament elements are secured at adjacent ends, the other ends of said filaments being bent inwardly toward said common axis and electrically connected one to the other at a common junction to form a self-supporting filament structure, a two-piece shield, said shield including a lower apertured member and a hollow frusto-conical upper member, said upper member being secured to said lower member, said common junction extending through said apertured member and into the space enclosed by said hollow frusto-conical member, said shield being secured to said filament structure by a fused connection between said common junction and said apertured member.

5. An electron tube comprising an evacuated envelope, a tubular anode which serves as a portion thereof, said anode being closed on one end and having an inwardly extending flange-like member adjacent its other end, a cage-type thermionic cathode having a plurality of spaced parallel filaments, said individual filament strands being bent inwardly adjacent one end and electrically connected at a common junction, substantially only the electron emissive portion of said cathode extending within said tubular anode, and a filament top shield including an apertured member and a hollow hat-shaped member secured thereto, at least part of said common junction extending through said apertured member and into the space defined by said hat-shaped member, said filament top shield being secured to said cathode.

6. An electron tube comprising an evacuated envelope, a hollow cylindrical anode serving as a portion thereof, one end of said anode being closed and an inwardly projecting flange-like member adjacent its other end, a cage type cathode extending at least partly within said anode, said cathode having a plurality of spaced parallel filament strands each bent inwardly adjacent one end and electrically connected to a common junction, a shield having a channel-shaped transverse section disposed about and along at least a part of each filament strand, a common support for each strand and the shield associated therewith, and a cathode top shield including an apertured member and a hollow hat-shaped member secured to said apertured member, at least a part of said common junction extending through said apertured member and into the space defined by said hat-shaped member, said filament top shield being secured to said cathode.

7. An electron tube comprising an evacuated envelope, a hollow cylindrical anode serving as a portion thereof, one end of said anode being closed, an inwardly projecting flange-like member adjacent the other end of said anode, a cage-type cathode extending at least partly within said anode, said cathode having a plurality of spaced parallel filament strands, each strand being bent

inwardly adjacent one end and electrically connected one to another at a common junction, a shield having a channel-shaped transverse section disposed about and along at least a part of each filament strand, and a cathode top shield including a disc-like lower member and a hollow hat-shaped upper member secured to said disc-like lower member, said lower member being secured to said cathode at said junction.

8. An electrode assembly comprising a plurality of filament elements disposed in circumferentially spaced parallel relation about a common axis, one end of each of said filament elements being bent inwardly toward said common axis and electrically connected one to another at a common junction point to form a self-supporting filament structure, a separate concave metallic shield extending along and about each of said filament elements with the open sides of said shields facing radially outwardly with respect to said common axis, a support structure for each shield, said support structure being integral with said shield, the other end of each of said filament elements being secured to the shield support structure of the shield associated therewith, said common junction extending through and secured to an apertured element, said apertured element being a part of a shielding structure which includes a frusto-conical element secured to said apertured element, said common junction extending through said apertured element and into the space enclosed by said frusto-conical element.

References Cited in the file of this patent

UNITED STATES PATENTS

2,143,916	Jonker et al.	Jan. 17, 1939
2,144,505	Mouromtseff et al.	Jan. 17, 1939
2,204,306	Harris	June 11, 1940
2,459,792	Chevigny	Jan. 25, 1949