

Jan. 26, 1965

L. G. LYON ETAL

3,167,679

CATHODE STRUCTURE

Filed March 14, 1961

3 Sheets-Sheet 1

FIG. 1

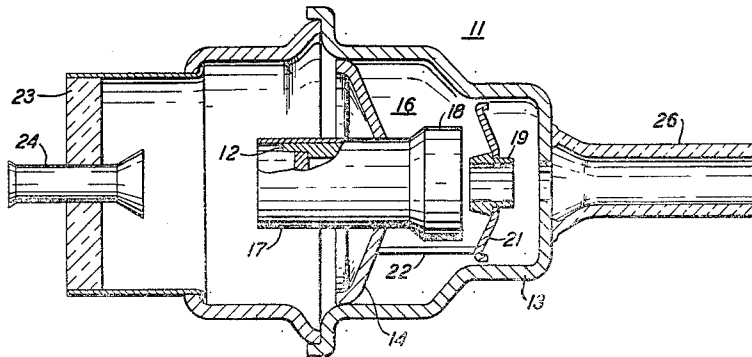
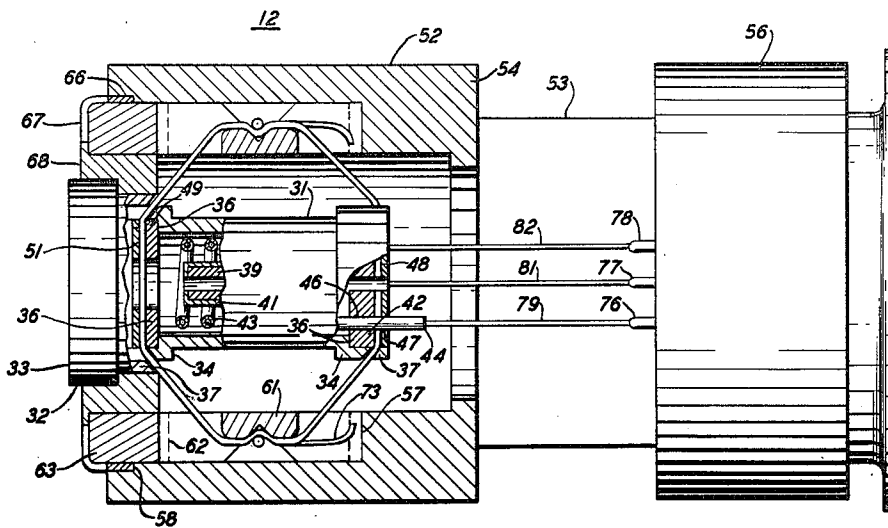


FIG. 2



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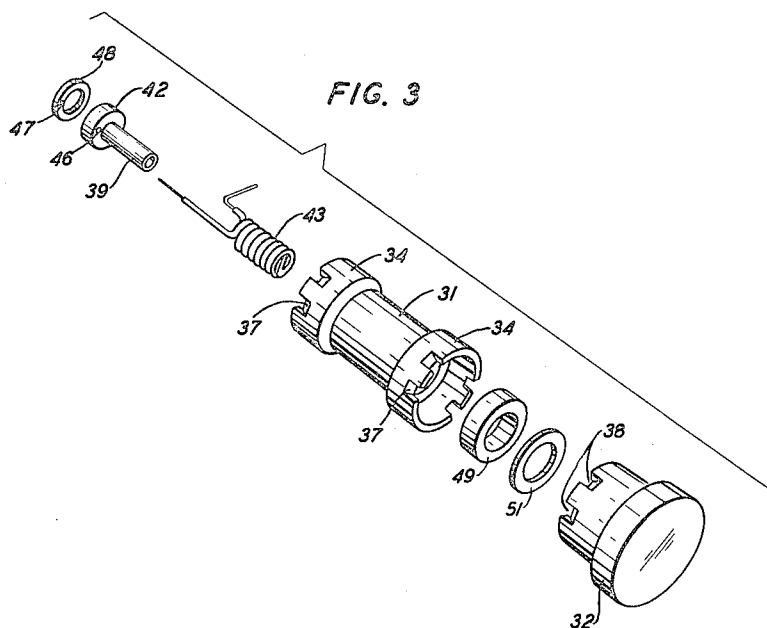
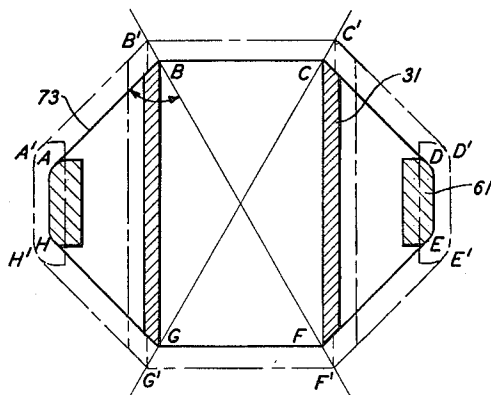


FIG. 5



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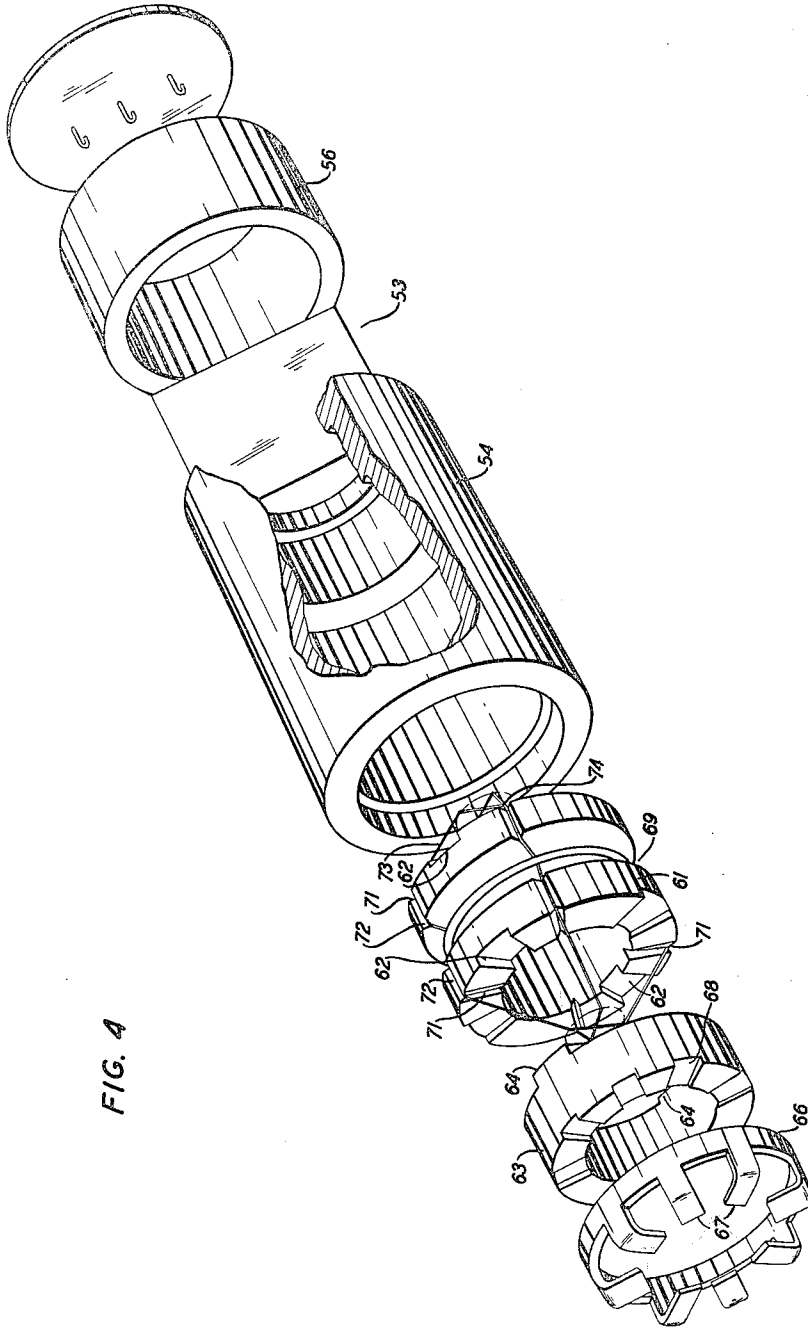
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FIG. 4



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CATHODE STRUCTURE

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9 Claims. (Cl. 313-270)

This invention relates to electron discharge devices and, more particularly, to a cathode structure for use in electron discharge devices of, for example, the traveling wave tube type.

Traveling wave tubes, in general, utilize the interaction between an electron beam and an electromagnetic wave traveling in close proximity to the beam to produce amplification of the wave. Such devices are well adapted for use in communications systems by virtue of the fact that they give high gain over an exceptionally broad band of frequencies in the microwave range. Because of these virtues, traveling wave tubes have proven to be quite useful tools in radio relay systems operating in the microwave range.

Ordinarily, in order to achieve high power gain in a traveling wave tube while maintaining the tube length within reasonable limits, a high density electron beam is required. To achieve sufficient electron emission from the cathode to provide a beam of the necessary density has, heretofore, required a high expenditure of power in the cathode heater circuit. This large expenditure of power arises, in part, from the necessity of providing a firm support for the cathode, which in turn results in an increase in thermal conductance from the cathode through the support. The heat conducted away from the cathode through the thermal paths thus created is wasted power, since it serves no useful function. Heretofore, efforts to reduce thermal conductivity by decreasing the number or extent of the thermal paths have had a direct effect on the strength and rigidity of the support. In the case of traveling wave tubes in overland communications systems, where large amounts of power are generally available and the tubes are relatively immobile, a compromise between heat losses and rigidity of cathode support is fairly simple to reach. On the other hand, where the traveling wave tube is used in airborne or space communications equipment, such as in missiles or satellites, very limited amounts of power are available and yet the cathode must be supported by a structure capable of withstanding enormous acceleration and vibrational forces. Under such conditions, there can be little or no compromise, the cathode must have a small power drain and it must be strongly supported.

It is an object of this invention to minimize the power drain of the cathode of an electron discharge device.

It is another object of this invention to enable the cathode of an electron discharge device to withstand large acceleration and vibrational forces without detriment to the proper functioning of the device.

These and other objects of the present invention are achieved in an illustrative embodiment thereof which comprises a cathode assembly for use in the electron gun of a traveling wave tube. The cathode assembly comprises a hollow tubular member having at one end thereof an electron emitting cap. Within the tubular member is an insulated heating coil for heating the cap to emission temperature. Surrounding the tubular member and spaced therefrom is a hollow metallic shell within which is mounted a slotted support member which also surrounds the tubular member.

It is one feature of the present invention that the tubular member is supported by the support member by

means of very fine wires which pass through the slots in the support member, through slots at the cap end of the tubular member, through slots in the support member, and through slots at the other end of the tubular member thereby forming a loop of wire. Each wire thus wound is fixed at its ends to the support member. With such a structure, the tubular member and cap are effectively suspended in a cradle made up of a plurality of wire loops.

It is another feature of the present invention that the wires are wound under a high degree of tension, but sufficiently within the yield limit of the material of which the wires are made that thermal expansion and contraction of the wires and the tubular member do not permanently deform the wires.

It is a further feature of the present invention that the angle that the wires make with the axis of the tubular member is such that the wires are subjected substantially exclusively to tension and compression forces during operation, under which conditions the wires extending between the support member and the tubular member effectively act as columns.

An additional feature of the present invention is that the wires are of a material having very low thermal conductivity, so that the principal heat losses are through radiation only.

These and other features of the present invention will be more readily apparent from the following detailed description, taken in conjunction with the accompanying drawing, in which:

FIG. 1 is a sectional view of the electron gun end of a traveling wave tube showing the location of the cathode structure of the invention;

FIG. 2 is a sectional view of the cathode structure of the invention;

FIG. 3 is an exploded perspective view of one portion of the cathode structure of the invention;

FIG. 4 is an exploded perspective view of another portion of the cathode structure of the invention; and

FIG. 5 is a diagrammatic view of the cathode structure indicating its behavior under varying thermal conditions.

Turning now to FIG. 1, there is depicted the electron gun end 11 of a traveling wave tube for purposes of illustrating the position of the cathode assembly 12 of the present invention. Inasmuch as the various parts of a traveling wave tube are well known in the art, the entire tube has not been shown in detail for purposes of clarity. That portion 11 of the traveling wave tube which is shown comprises a metallic envelope portion 13 within which is mounted, by means of a mounting member 14, the electron gun assembly 16. Gun assembly 16 comprises a cathode shield 17, within which is mounted the cathode assembly 12 of the present invention, and further comprises a beam forming electrode 18 and an accelerating anode 19 which is maintained in spaced relation to the beam forming electrode by member 21 and post 22. For simplicity, the various voltage leads to the electrodes of the gun 16 have not been shown since they are conventional and form no part of the present invention. The base end of the envelope portion 13 is sealed by means of plate 23 of glass or other suitable material and tubulation 24. The gun end of member 11 is sealed to a glass envelope portion 26 which contains the helix, not shown, of the traveling wave tube.

Turning now to FIG. 2, there is shown in detail a section through the cathode assembly 12 of the present invention. Inasmuch as a sectional view, while sufficient for showing the various elements and parts of the cathode structure, does not give a three-dimensional aspect to the structure, which in the case of the present invention is highly desirable, in the following description of FIG. 2 reference should also be made to FIGS. 3 and 4

so that a clear understanding of the cathode structure may be had.

Cathode assembly 12 comprises a tubular member 31 of nickel or other suitable material at the upper end of which, as viewed in FIG. 2, is attached a cap 32. The surface 33 of cap 32 is coated with electron emissive material such as barium and strontium carbonate. Cap 32 is attached to member 31 preferably by welding. Tubular member 31 is provided with enlarged portions 34 at each end thereof, which are bored out to form shoulders 36 at both the upper and lower ends of member 31. Enlarged portions 34 have a plurality of slots 37 therein which are best seen in FIG. 3 where, in the embodiment shown, each enlarged portion 34 has four slots. Cap member 32 likewise has four slots 38, which are circumferentially disposed so as to mate with slots 37 when member 31 and member 32 are assembled and welded. Within member 31 is mounted a core 39 of molybdenum or other suitable material which has an insulating coating 41 of aluminum oxide thereon, and has an enlarged flange portion 42 which butts against shoulder 36 of member 31. Flange 42 is welded to member 31 to maintain core 39 in proper position. Surrounding core 39 is a double helix heater 43 of tungsten or other suitable material, having an insulating coating of aluminum oxide thereon. One lead 44 of heater 43 passes through an aperture 46 in flange 42 and through an aperture 47 in a washer 48, the purpose of which will be explained more fully hereinafter. The other lead, not shown, of heater 43 may be attached to member 31 as by welding or it may be brought out through flange 42 and washer 48 in the same manner as lead 44. At the upper end of member 31 a plate 49 rests on shoulder 36 and is welded to member 31 in the same manner as flange 42. A washer 51, the purpose of which will be explained more fully hereinafter, is likewise situated in the bore of the enlarged portion 34 of member 31. Surrounding the tubular member 31 and cap 32 is a shell 52 of molybdenum or other suitable material, which, as best seen in FIG. 4, comprises a member having a large slot 53 cut in one side thereof to a depth extending past the center line of the cylinder, thereby forming a first cylindrical portion 54 which surrounds members 31 and 32, and a second cylindrical portion 56 through which the necessary voltage leads extend. Portion 54 is bored out to form a first shoulder 57 and a second smaller shoulder 58. Within member 54 and resting on shoulder 57 is a mounting member 61, which will be discussed more fully hereinafter. Mounting member 61 has a pair of keyways 62 cut therein, as best seen in FIG. 4, and resting upon mounting member 61 is a retaining ring 63 which has a pair of keys 64 which mate with keyways 62. Retaining ring 63 is, in turn, retained in position by a castellation 66, which comprises a ring of nickel having a plurality of lugs 67 which are bent over and reside in slots 68 in member 63. Castellation 66 rests upon shoulder 58 in member 52 and is joined to member 52 as by welding.

Support member 61, as best seen in FIG. 4, comprises a cylindrical member of molybdenum which has a peripheral V-shaped groove 69 located midway between the two end faces of the member. Each end face of the member 61 has a pair of diametrically opposed keyways 62, the purpose of which has already been pointed out. In addition, each end face of member 61 has two pairs of diametrically opposed V-shaped slots 71. Each pair of slots 71 may be oriented 90 degrees with respect to the other, or any other suitable angle may be chosen depending upon the ease of fabrication. The angle between the pairs of slots should not, however, be too small. Extending from each of the slots 71 and longitudinally of the member 61 is a V-shaped groove 72, which extends to the other end face of the member 61 so that

each slot 71 on one end face is joined to the corresponding slot 71 on the other end face.

Tubular member 31 is supported within the supporting member 61 by means of fine support wires 73 and 74, which are of a material such as Nilvar which has a low thermal conductivity and a high tensile strength. The manner in which the wires 73 and 74 act as a support can best be understood by a brief explanation of the manner in which they are wound relative to member 61 and member 31. Wire 73, for example, is welded at one end to support member 61 at the bottom thereof, as best seen in FIG. 2. The wire is then passed through a longitudinally extending V-shaped slot 72, through the corresponding V-shaped slot 71 on the left-hand end face of member 61, as viewed in FIG. 4. It is then passed under tension through one of the slots 37 of member 31, across the top of plate 49, through a diametrically opposed slot 37 in member 31, through a V-shaped slot 71 in the left-hand end face of member 61 which is diametrically opposed to the V-shaped slot 71 through which the wire was first passed, along the corresponding longitudinally extending V-shaped slot 72, through a corresponding V-shaped slot 71 on the other end face of member 61, through the slot 37 in member 31, across the bottom of the flange 42 of core member 39, through a diametrically opposed slot 37 in member 31 through a V-shaped slot 71 in the right-hand end face of member 61, as viewed in FIG. 4, along the same longitudinally extending slot 72 along which it was first passed, through the same slot 71 in the left-hand end face of member 61 through which it was first passed, through the same slots 37 in member 31 and back along the same slot 71, 72 and 71 along which it was passed in the first winding, and is welded to the right-hand end face of member 61, as viewed in FIG. 4. From the foregoing it can be seen that the wire 73 thus wound forms a loop of one and one-half turns. In order to adjust to achieve the optimum tensile stress on the wire after the winding operation and after the wire 74 has been wound in the same manner through the other corresponding pairs of slots, a molybdenum wire is wound in groove 69 in member 61 to compress the wires 73 and 74 slightly within the groove 69, thereby increasing the tension on wires 73 and 74 to the desired value. The tension on the wires should be sufficiently less than the yield point of the material to allow for thermal expansion and contraction of the wire without deformation. After the wires 73 and 74 have thus been wound, washers 48 and 51 are tack welded in place, the tacks being made in the spaces left between the wires. The wires themselves are then brazed to the member 61 in the slots 72. From the foregoing description and from an examination of FIG. 4 it can be seen that the member 31 with the cap 32 affixed thereto is supported within a cradle of loops formed by the wires 73 and 74. Dotted lines are shown in FIG. 4 to indicate the two ends of member 31 and their relationship to the wires. There is no actual physical connection between the wires 73 and 74 and member 31, although washers 48 and 51, after tack welding, compress the wires sufficiently to hold them rigidly in place.

The base portion 56 of member 52 has mounted therein three metallic lead lugs 76, 77 and 78, as seen in FIG. 2. Lug 76 serves as a lead-in conductor for heater lead 44 and is joined thereto by means of a lead 79. Either of lugs 77 or 78 may be used as another lead-in conductor for the other heater lead if it is so desired, although in the embodiment here shown, as pointed out before, the other heater lead is simply joined to the member 31. In the embodiment here shown lugs 77 and 78 are connected by means of thermal couple leads 81 and 82, respectively, to the member 31. During assembly of the cathode structure 12 within the traveling wave tube and after the tube has been sealed off the thermal couple leads permit monitoring of the cathode temperature so that the precise

relationship between power drain and cathode temperature for each individual tube may be readily determined. Other than this, the thermal couple leads are not used.

Referring now to FIG. 5, there is depicted schematically the tubular member 31, the support member 61 and wire 73 for purposes of illustrating some of the operational stresses which the elements undergo during various stages of fabrication and during operation.

Initially in the nonoperating state the member 31, the support 61 and the wire 73 are oriented relative to each other as shown by the solid lines. During brazing and bake-out operations, because of thermal expansion of the various elements, the members 31 and 61 and the wire 73 will all expand to the position shown by the dotted lines and the wire will extend along the path A', B', C', D', E', F', G' and H'. On the other hand, during operation, that is, when the cathode only is heated, the member 61 does not expand but the member 31 does and the wire 73 will lie along the path A, B', C', D, E, F', G', H. It has been found that with a proper choice of materials, in this case molybdenum for the member 61, nickel for the member 31 and Nilvar or Invar for the wire, their coefficients of expansion are such that if the angle ABF is made 90 degrees the wire will not be subjected during brazing, bake-out and operation to any stresses other than tension and compression, and furthermore, as can be seen in FIG. 5, the length of the wire from A-B, from A'-B' and from A-B' is substantially the same so that there is no deformation of the wire. With such an arrangement, therefore, the wire 73 as well as the wire 74 act as columns in supporting the member 31.

From the foregoing, it can be seen that the cathode of the present invention achieves the objects for which it was made. The Nilvar wires, because of their small diameter and the low heat conductivity of Nilvar, present very high impedance paths to heat flow and the principal heat losses in the cathode are due to radiation, whereas in conventional cathodes conduction losses are at least eighty percent of the total heat loss. As a consequence, the power drain of the cathode is quite small, in the actual structures thus far made a power of one watt is sufficient to heat the cathode to well over 700 degrees C. which is the operating temperature of the cathode. Conventional cathode structures used in travelling wave tubes require from five to ten watts of power to heat the cathode to this operating temperature.

The structural strength of the cathode assembly surpass the strength of most conventional cathode structures. Tests thus far have proven the cathode structure of the present invention to be capable of withstanding acceleration forces greater than 40 G's at frequencies between 50 c.p.s. and 3,000 c.p.s. Because of the plate 32 being mounted at one end of the member 31 and no compensating weight being mounted at the other end of member 31, the center of gravity of the assembly of members 31, 32, 39 and 43 is toward the emission end. Ordinarily this would make the assembly more susceptible to vibration than if the center of gravity were exactly centered in the assembly, but inasmuch as each of the wires 73 and 74 passes over the upper end of member 31, as viewed in FIG. 2, twice, thereby in effect giving eight columnar supports for the upper end and a consequent greater rigidity, vibrational effects are minimized.

The core member 39 and its insulating coating 41 are of a diameter such that the heater coil 43 is closer to the core than to the inside walls of member 31. Therefore, if the heater vibrates during operation it cannot vibrate sufficiently far to strike the walls of member 31.

The embodiment of the present invention described in the foregoing achieves the desired objects. It is to be understood, however, that the embodiment shown is by way of illustration of the principles of the invention and other embodiments or modifications of the present embodiment may be readily apparent to workers skilled in

the art without departing from the spirit and scope of this invention.

What is claimed is:

1. For use in an electron discharge device, a cathode structure comprising a tubular member having an electron emissive surface at one end thereof, a heater within said tubular member, and a supporting structure for said tubular member comprising a slotted annular member surrounding said tubular member and spaced therefrom, and a plurality of stressed wires, each of said wires extending from the slots in said annular member to both of the ends of said tubular member, the ends of said wires being secured to said annular member.

2. For use in an electron discharge device, a cathode structure comprising a tubular member having an electron emissive surface at one end thereof and a plurality of slots in said tubular member adjacent the electron emissive end and at the opposite end thereof, a heater within said tubular member, and a supporting structure for said tubular member comprising a slotted annular member surrounding said tubular member and spaced therefrom, and a plurality of stressed wires each of said wires extending from the slots in said annular member and through the slots in both of the ends of said tubular member the ends of said wires being secured to said annular member.

3. For use in an electron discharge device, a cathode structure as claimed in claim 2 wherein said wires are of a material having sufficient resistance to the conduction of heat to minimize heat losses and having a tensile strength sufficient to prevent deformation due to thermal expansion and contraction.

4. For use in an electron discharge device, a cathode structure comprising a tubular member having a plurality of slots at each end thereof, an electron emissive cap member having slots therein which match with the slots in one end of said tubular member, said cap member being affixed to said one end, a heater within said tubular member, and a support structure for said tubular member comprising a slotted annular member surrounding said tubular member and spaced therefrom, and a plurality of stressed wires each of said wires extending from the slots in said annular member through the slots at each end of said tubular member, and a cylindrical shell of metallic material within which said support member is mounted, the ends of said wires being secured to said annular member.

5. For use in an electron discharge device, a cathode structure comprising a cylindrical member having an electron emissive surface mounted on one end thereof and a supporting structure for said cylindrical member comprising a slotted annular member surrounding said cylindrical member and spaced therefrom, and a plurality of stressed wires each of said wires extending from the electron emissive end of said cylindrical member through the slots in said annular member, the ends of said wires being affixed to said annular member.

6. For use in an electron discharge device, a cathode structure as claimed in claim 5, wherein said wires are of a material having sufficient resistance to the conduction of heat to minimizing heat losses and having a tensile strength sufficient to prevent deformation due to thermal expansion and contraction.

7. A supporting structure for an electron emissive cathode comprising a cathode, a plurality of wire loops, the wires of said loops passing through slots in an annular member surrounding said cathode whereby said wires are held under tension, the cathode being mounted within said loops and in contact therewith adjacent the ends of said cathode.

8. A cathode structure as claimed in claim 7, wherein the wires forming said loops are of a material having sufficient resistance to the conduction of heat to minimize heat losses and having a tensile strength sufficient to

prevent deformation due to thermal expansion and contraction.

9. For use in an electron discharge device, a cathode structure comprising a hollow cylindrical member having an electron emissive cap mounted at one end thereof, a heater within said cylindrical member, and a supporting structure for said cylindrical member and said cap comprising a slotted annular member surrounding said cylindrical member and spaced therefrom, and a plurality of stressed wires extending from the slots in said annular member to both of the ends of said cylindrical member at an angle to said cylindrical member, the angle formed between said wires and said cylindrical member being so chosen that said wires are subjected

to tensile and compressive stresses only during the operation of said cathode, each of said wires being secured to said annular member.

References Cited in the file of this patent

UNITED STATES PATENTS

Re. 22,378	Bowie	Sept. 21, 1943
2,397,233	Bingley	Mar. 26, 1946
2,861,211	Brown et al.	Nov. 18, 1958
2,874,209	Bisterfeld	Feb. 17, 1959
3,105,165	Kohl	Sept. 24, 1963

FOREIGN PATENTS

1,098,622	Germany	Feb. 2, 1961
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