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2,594,897

CATHODE STRUCTURE FOR ELECTRON DISCHARGE TUBES

Filed Sept. 19, 1945

3 Sheets-Sheet 1

FIG. 2

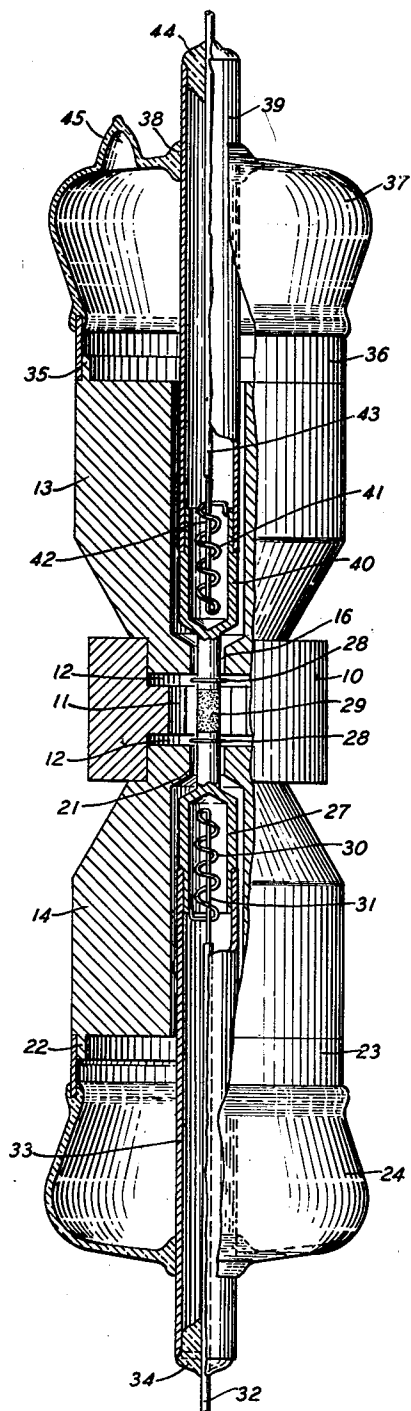
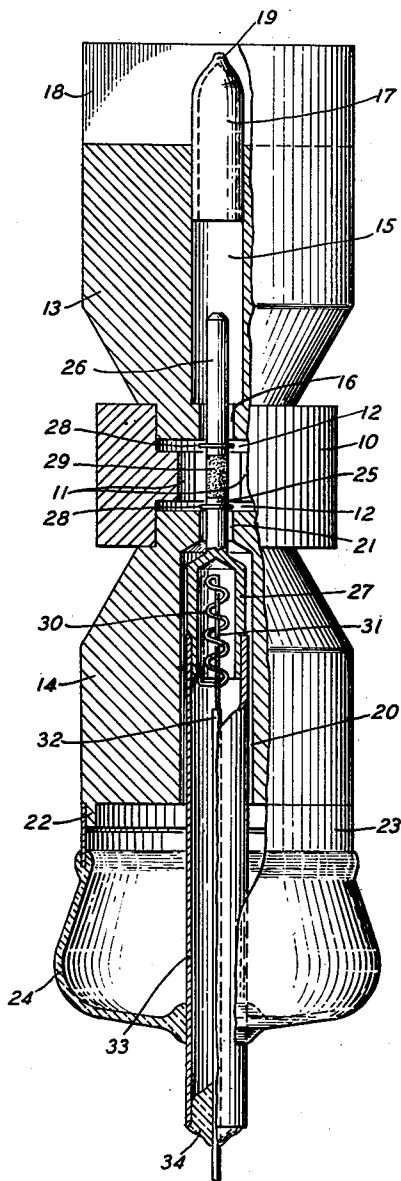


FIG. 1



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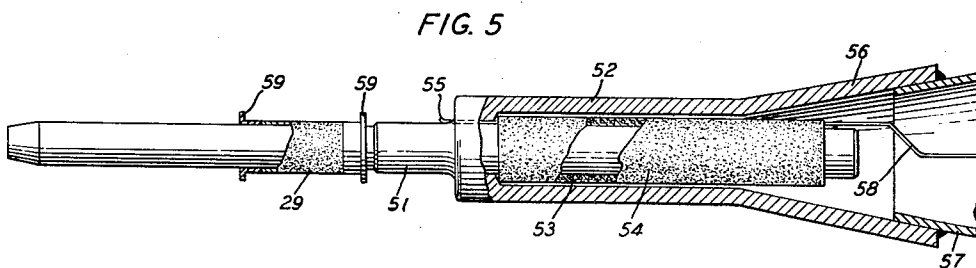
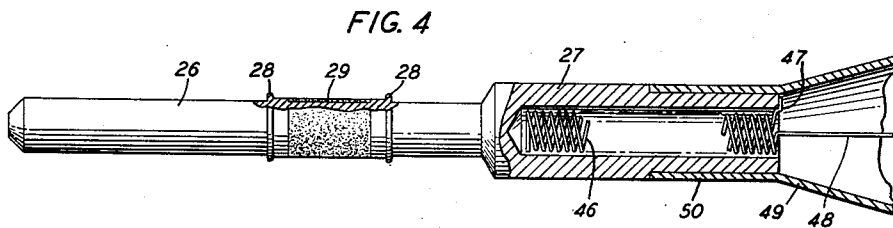
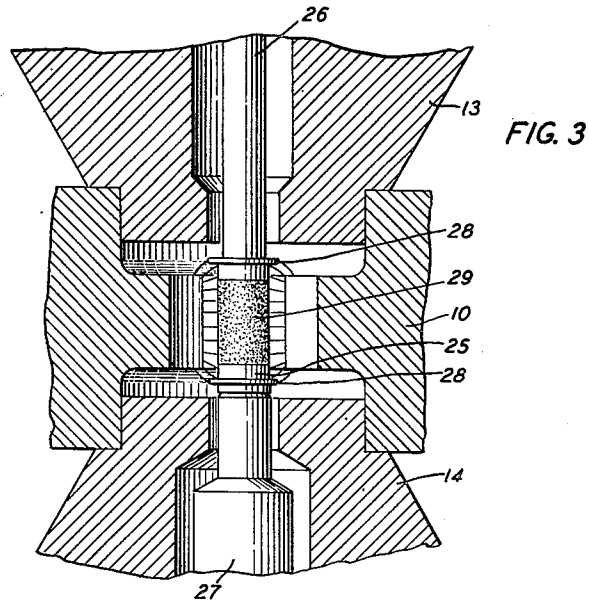
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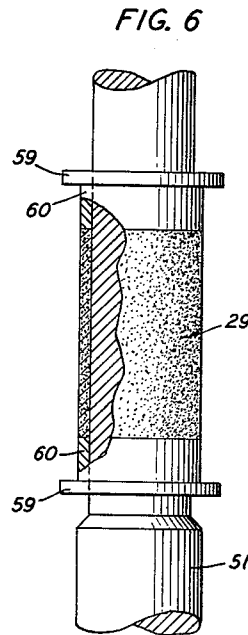
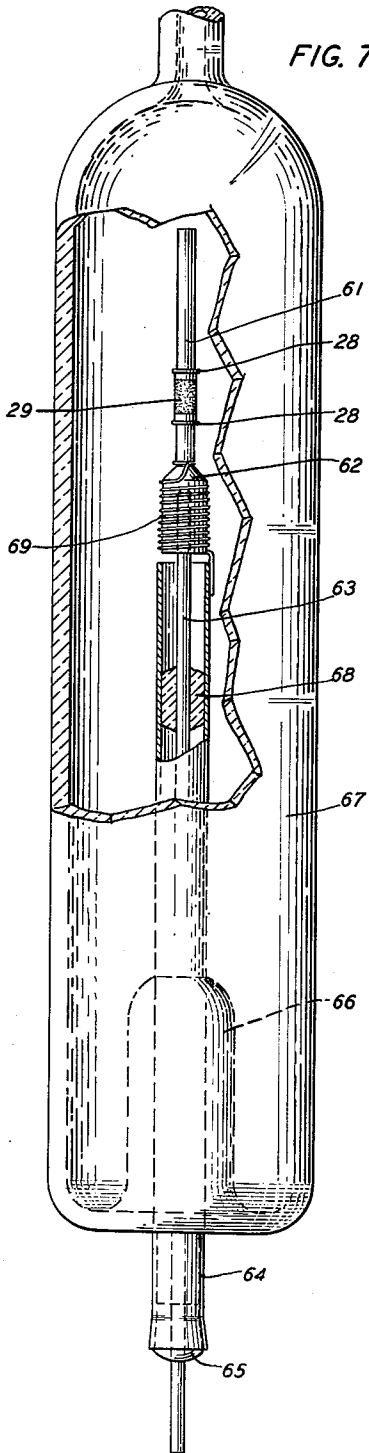
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3 Sheets-Sheet 3



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CATHODE STRUCTURE FOR ELECTRON
DISCHARGE TUBES

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14 Claims. (Cl. 313—337)

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This invention relates to electron emitters for electron discharge devices and more particularly to such emitters for supplying copious emission of electrons in high power transmitting devices especially suitable for use in ultra-high frequency systems.

In ultra-high frequency transmitting devices, especially of the magnetron type, the emission of electrons is furnished by a cathode of the indirectly heated type which is initially energized by an enclosed heater and when the cathode has been brought to the proper emission temperature, the heater is deenergized and the cathode maintained in an emissive state by bombardment heating. Difficulties have been experienced with the usual form of cathode structure due to overheating of the emissive coating, partly because of lack of heat dissipation and partly because of lack of control of the temperature of the coating, which is readily fused and rendered inactive by excessive heating. Furthermore, the frangible coating is subjected to disintegration under these conditions so that active emissive substances are transported to other electrodes and surfaces in the device and when heated produce destructive effects in the device causing depreciation of the operating efficiency or rendering the device unsuitable for further service.

An object of this invention is to prevent these effects by controlling the temperature of the emitter while still preserving the manifest qualities and utility of bombardment heating of the emissive material on the cathode.

Another object of the invention is to efficiently construct the cathode so that heat dissipation is enhanced whereby the cathode is held at a uniform temperature throughout the operating period of the device.

A further object of the invention is to segregate the internal heater element of the cathode from the high temperature zone or emission path of the cathode so that the emissive portion of the cathode has a solid cross-section to stabilize the heat energy distribution in the cathode assembly.

Still another object of the invention is to fabricate the cathode so that highly refractory metals may be employed whereby the heat dissipation constant is maintained at a high level to prevent relaxation effects in the active emissive coating on the cathode.

A further object of the invention is to facilitate the organization of the cathode with other closely related electrodes so that temperature changes are compensated to maintain reciprocal rela-

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tionship of the cathode with other electrodes in the device.

These objects are attained in accordance with various aspects of the invention by providing a cathode structure including an elongated solid core rod of highly refractory metal having high heat conductivity and radiation properties, an intermediate portion of which is coated with suitable electron emissive material serving as the emitting surface. The coated portion of the core rod is initially heated to emission temperature by one or more heater elements situated at one or both ends of the rod to energize the coating by conduction through the rod.

In accordance with a feature of the invention, the heater element may be mounted within a cavity of the rod or applied to the exterior of the rod. In the latter case, a shield may enclose the heater element to conserve the energy conveyed through the solid cathode.

Another feature of the invention relates to the extension of the cathode rod whereby heat dissipation is facilitated to maintain a uniform temperature in the cathode assembly.

A further feature of the invention relates to the stabilization of the cathode assembly in the device in relation to the anode to compensate for expansion due to heat variation. This is accomplished by providing a sleeve extension on the cathode rod of a metal having low expansion characteristics so that "creeping" of the cathode is prevented and the collateral relationship of the cathode and anode is maintained substantially constant.

These and other features and advantages of the invention are explained in more detail in the following description and shown in the accompanying drawings.

Fig. 1 illustrates one construction, shown partly in section, of a high frequency generator device embodying a cathode or emitter constructed in accordance with this invention.

Fig. 2 is an elevational view, partly in cross-section, of a modified device having an emitter heated from opposite ends.

Fig. 3 is an enlarged view of the central portion of the device of Fig. 1, shown in cross-section, to illustrate the electric field present between the active surfaces of the emitter and anode.

Fig. 4 shows one form of an emitter to be employed in the device of Fig. 1, a portion being broken away and another portion shown in cross-section to more clearly illustrate the construction.

Fig. 5 illustrates another form of the emitter assembly, shown partly in cross-section to illus-

trate the location of the insulated heater winding in a conduction type cathode.

Fig. 6 is an enlarged view of a portion of the emitter of Fig. 5, with a part shown in cross-section to illustrate the emissive coating on the active portion of the emitter; and,

Fig. 7 illustrates another form of the emitter mounted in an enclosing vessel, showing the vessel broken away and a portion of the construction in cross-section to bring out details of the assembly.

Referring to Fig. 1, the invention is illustrated as embodied in a high frequency generator device of the magnetron type having a central cylindrical block anode or output electrode 10, preferably of copper, provided with multicavities 11 on the inner boundary to tune the generator to the desired range of frequencies to be propagated as output energy at high power levels. Both ends of the anode are recessed adjacent the cavities to provide chambers 12 which are terminated by cylindrical pole-pieces 13 and 14, preferably of steel, brazed in the recesses of the anode. The pole-piece 13 is provided with a central passageway 15 communicating with a smaller diameter channel 16 which adjoins the upper cavity 12 of the device, the channel 16 being slightly smaller in diameter than the central cavity of the anode. The passageway 15 is fitted with a metallic sealing tube 17 which extends into a transverse slot 18 in the outer end of the pole-piece 13, the tube being pinched at 19, to seal the device after a high vacuum is produced in the device.

The pole-piece 14 is provided with a central passageway 20 leading into a smaller channel opening 21 adjacent the lower cavity 12 of the anode. The outer end of the pole-piece 14 has a projecting ring 22 formed adjacent the periphery which is brazed or soldered to a separate sleeve or band 23, preferably of a nickel-iron-cobalt alloy metal, such as "Kovar," having the desired low expansion characteristics to readily seal to a hard glass, such as certain types of borosilicate glass, for insulating the input electrode element from the anode and casing of the device. The "Kovar" sleeve is sealed to a bulbous glass portion 24 having a central aperture coaxial with the aligned passageways extending through the anode and pole-pieces.

A solid cylindrical metallic cathode or emitter is centrally mounted within the device. This emitter must produce a copious supply of electrons across the discharge path to the anode in order to generate sufficient power output for which the device is designed and at the same time must withstand the intense heat generated in the device during operation. In order to accomplish these results and also maintain a long operating life, it is essential that the cathode be extremely rugged yet delicately constructed so that it performs its appropriate functions in the cavity of the anode without deleteriously altering the prescribed values of inductance and capacity of the resonant chambers within the anode. Further, it should not cause instability due to warping, elongation and short-circuit contact in the confined areas of the anode. These attributes are efficiently achieved in accordance with this invention by employing a conduction type emitter or cathode of solid construction so that heat energy is transmitted and dissipated with high efficiency and the cathode attains a long operating life and insures top performance in the operation of the device over a large power range.

The cathode or emitter is formed of a solid

cylindrical rod or core of highly refractory metal, such as molybdenum, tungsten, steel, nickel or nickel alloy, and includes an intermediate active portion 25 located in the anode region, an elongated extending portion 26 projecting into the pole-piece 13 and a hollow cavity portion 27 projecting into the pole-piece 14. The central active portion is formed with spaced annular beads or rings 28 which are of slightly less diameter than the small channels in the oppositely disposed pole-pieces. The rings are positioned midway in the resonant chambers 12 on opposite ends of the anode and define the limits of the electric field between the anode and cathode, as shown in Fig. 3, to concentrate the electric lines of force near the ends of the active surface so as to limit the region of electron flow.

The central portion of the cathode adjacent and between the rings 28 is undercut to a suitable depth to receive a coating matrix 29 of highly active electron emissive material, for example a mixture of suitable oxides and metal powder, such as oxides of alkaline earth metals, specifically barium, strontium and calcium as compounds or salts which are decomposed to the oxides and activated in the final processing of the device, the metal powder being particularly nickel particles intermingled with the oxides for increasing the conductivity of the emissive coating. The matrix is relatively thick and applied as a spongy semi-porous layer which is heated to produce coalescence in the matrix and positive bonding to the solid metal surface or core of the cathode. Other highly emissive materials may be applied to the cathode either with or without other metal powders, to produce the active emitter matrix for generating a copious supply of electrons in the anode discharge path. The solid core cathode produces a construction of sufficient strength to withstand the excessive temperatures produced at the cathode surface by electron bombardment during operation and facilitates the removal of heat so as to prevent excessively high cathode surface temperature through the heat distribution faculty of the solid mass of metal in contact with the coating.

The cavity portion 27 of the cathode structure is made of high conductivity material to conduct heat from the heater to the active coating on the solid core so as to initiate electron emission. It forms a heat conserving shield or housing for an internal heater element 30 formed of a loose spiral of tungsten wire having an insulating oxide coating thereon, such as aluminum oxide, to prevent contact of the heater helix with the shield portion 27 of the cathode. One end of the heater helix is attached to the shield portion 27 and the other end is welded to a central tungsten support rod 31 which is joined to a long rod 32, of "Kovar" alloy sealed in the external end of a tubular metallic support member 33, by a glass bead 34, the inner end of the tubular support member 33 being attached to a reduced wall portion of the cathode structure by brazing or welding. The tubular support axially mounts the cathode structure in accurate position in the anode space and because of the low heat conductivity of "Kovar" prevents any appreciable heat flow from the heater chamber to the glass seal on which the "Kovar" cylinder is mounted, the tubular support being rigidly mounted in the bulbous glass portion 24 of the vessel by being sealed in the glass portion 24 adjacent to the terminal end of the tubular member. The tubular support 33 is formed of "Kovar" alloy, which

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has a low expansion characteristic, to eliminate to a large extent the elongation of the cathode core due to temperature changes. The advantages of this construction are evident when it is considered that the spaces between the annular beads 28 and the ends of the pole-pieces are quite minute and excessive expansion of the cathode cannot be tolerated in the confined areas of the anode resonant cavities of the assembly.

The heater element 30, in accordance with one feature of this invention, is located beyond the intense heating zone of the device but facilitates the initial heating of the coating 29 by conduction through the solid core of the cathode. After the coating has reached emission temperature and a radio frequency field is established in the anode area, energy to the heater element may be discontinued and the cathode is then maintained at emission temperature by back-bombardment from the anode. While the anode bombardment heating causes greater heating of the coating than is produced by the heater element, the solid construction of the cathode core facilitates the rapid distribution of the excessive heat energy along the cathode length and dissipation of the excess is influenced by the radiation properties of the material of the core and the elongated extensions of the cathode projecting into the cooler pole-pieces of the device. Furthermore, the solid construction of the cathode core materially strengthens the assembly since the large mass of metal in the core offsets warping or fracture of the cathode and the solid core presents a low impedance to heat transmission particularly where it passes through the restricted apertures in the pole-pieces at opposite ends of the device.

The construction of the device in Fig. 2 is particularly adapted to utilize an emitter assembly of the quick heating type wherein the cathode is initially brought to emission temperature by heating elements disposed in opposite ends of the cathode. In this construction, the upper pole-piece 13 has an annular projection 35 on the outer end similar to the pole-piece 14 to receive a "Kovar" sealing ring 36 which is hermetically sealed to a vitreous bulbous portion 37 having an annular seal 38 engaging the outer wall of a "Kovar" tubular support member 39. The latter is connected at its inner end to an enlarged cavity portion 40 on the opposite end of the cathode assembly from the cavity portion 27 located within the pole-piece 14. A second insulated helical heater element 41 is mounted within the cavity of the portion 40 and is connected thereto at one end and also to a central support rod 42 joined to a "Kovar" conductor 43 extending coaxially through the tubular member 39, the conductor 43 being sealed in the outer end by a glass bead 44. The emissive coating 29 on the cathode is rapidly energized by conduction through the oppositely disposed heater elements 30 and 41 either in series through the conductors 32 and 43 or in parallel through the coaxial conductors at opposite ends of the device. After the heater elements are disconnected and the emitter coating is energized through anode bombardment, the enlarged cavity portions 27 and 40 of the cathode assembly efficiently dissipate the heat energy generated in the cathode assembly and the low expansion tubular members 33 and 39 further restrict elongation of the cathode assembly to insure proper spacial relation between the annular rings 28 on the cathode and the anode cavities and pole-

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piece ends adjacent thereto. The device may be evacuated and processed for completion through the bulbous glass portion 37 of the device and finally sealed off as indicated at 45.

Fig. 4 shows the detailed construction of a conduction type cathode illustrative of one embodiment of this invention which is formed of a machinable highly refractory metal, such as molybdenum, steel or nickel alloy, in which the reduced diameter section 26 is solid throughout the length thereof and annular beads 28 are formed thereon in spaced relation intermediate the ends of the uniform diameter section. A portion between the rings is undercut to receive the emissive coating 29, which is flush with the surface of the elongated section 26. The other section 27 is of larger diameter and is provided with a central cavity for receiving a double helical insulated heater element 46, of tungsten wire, having one end connected to the open end of the cavity section 27, as shown at 47, and the other end 48 extending coaxially through a tapered or conical "Kovar" sleeve 49 having a cylindrical portion fitted into an undercut circular recess 50 in the cavity portion 27 of the cathode assembly.

Fig. 5 illustrates a modification of the conduction type cathode, in accordance with this invention, in which the main cathode core rod 51 is formed of a non-machinable metal, such as tungsten, to withstand higher power ratings and increase the structural rigidity of the assembly. In this construction a metallic shield member 52, preferably of molybdenum, surrounds substantially one-half the length of the conduction core rod of the cathode, to form a heat conserving shield for a helical tungsten heater element 53 wound on the length of the rod 51 enclosed in the shield and embedded in a coating of insulating material 54. One end 55 of the heater element 53 is anchored between the core rod 51 and the shield 52 at the intermediate junction of these elements and is welded or brazed to the rod and shield to rigidly mount the core rod in the shield. The heater element portion of the core rod is substantially enclosed within the shield to segregate the heater element from the active portion of the cathode. A conical portion 56 of the shield is welded or brazed to a "Kovar" conical tubular member 57 and the outer end 58 of the tungsten heater element extends coaxially through the "Kovar" tubular member to be sealed in the outer end of the magnetron device to terminate the cathode assembly. Since the tungsten core rod cannot be machined to form the spaced annular rings for limiting the electric field to the active portion of the cathode, metallic annular flange rings 59 having sleeve portions 60 are spaced on the elongated extension of the core rod with the sleeve portions in opposed relation, as shown more clearly in Fig. 6. The flanged rings are formed of a low expansion metal such as a nickel-iron-cobalt alloy, and are preferably shrink fitted on the core rod to rigidly position the limiting flange members on the solid core of the cathode. In this construction, as shown in Fig. 6, the thickness of the sleeve portions 60 of the rings determines the thickness of the emissive coating 29 applied to the solid core between the rings so that the coating is flush with the surface of the rings and defines the extent of the coating upon the solid core cathode.

Fig. 7 shows another modification of a cathode assembly constructed in accordance with this invention in which the conduction type cathode has

an elongated cylindrical solid portion 61 and an enlarged diameter portion 62 centrally drilled to receive a central support rod 63. The rod 63 is sealed in a coaxial tubular conductor 64, of "Kovar" alloy, by a bead 65, the tubular support being fused in a glass stem 66 of an enclosing vessel 67. The central support rod 63 of the cathode assembly is additionally supported in the tubular member 64 by another glass bead 68, to prevent vibration of the support rod in the assembly. An insulated heater element 69, preferably of tungsten wire, is wound on the enlarged diameter portion 62 of the cathode with the ends thereof connected to the cathode rod and the tubular support member 64 for heating the active portion of the cathode by conduction. The coating 29 is terminated by the annular rings 28, formed on the elongated cathode surface. While this figure shows the cathode assembly mounted alone in the enclosing vessel, it is, of course, understood that the same cathode construction may be incorporated in the device of Fig. 1, to constitute a completely operable device.

While the invention has been disclosed in various forms to achieve the concepts of the invention by heat distribution and radiation in the solid cathode assembly, it is, of course, understood that various modifications may be made in the detail assembly of the cathode or emitter without departing from the scope of the invention as defined in the appended claims.

What is claimed is:

1. A high power electron emitter comprising a solid metallic core having a portion of its surface coated with emissive material, and a heater element enclosed in one end of said core for heating said surface by conduction through said core.

2. A high power electron emitter comprising a solid elongated metallic core having an intermediate portion of its surface coated with emissive material, a heater element surrounding one end of said core for initially heating said surface by conduction to emitting temperature, and a heat radiation portion on the other end of said core beyond said intermediate coated portion.

3. A high power electron emitter comprising a solid metallic core having a portion of its surface coated with emissive material, a heater element surrounding one end of said core for initially heating said surface by conduction, and a metallic shield surrounding said heater element.

4. A high power electron emitter comprising a solid metallic core having a portion of its surface coated with emissive material, a heater element enclosed in one end of said core for heating said surface by conduction through said core, and a hollow metallic extension attached to one end of said core and formed of a metal of low heat expansion properties.

5. A conduction type cathode comprising a solid elongated rod, a portion thereof intermediate the ends having an emissive coating affixed in heat transfer relation thereto, one end of said rod having a hollow cavity, and a heater element mounted within said cavity.

6. A conduction type cathode comprising a solid tungsten rod, an intermediate portion thereof having a thick coating of electron emission substances, flanged rings secured to said rod at opposite ends of said coating, a heater element surrounding one end of said rod, and a cover shield encircling said element and affixed to said rod.

7. A conduction type cathode comprising a solid tungsten rod, an intermediate portion there-

of having a thick coating of electron emission substances applied thereto, an insulating coating on one end of said rod, a helical heater element embedded in said insulating coating, and a conical shield extending over said heater and insulating coating and being joined to said rod intermediate both coatings.

8. A cathode structure for electron discharge devices comprising a solid metallic elongated member having an intermediate electron emissive portion adapted to be surrounded by an anode of the device and having also a hollow portion at one end, a heater element within said hollow portion, one end of said element being connected to said hollow portion and the other end extending coaxially from said hollow portion, a tubular metallic extension joined to said hollow portion, and a hermetic insulating seal joining said extending end of said heater element to the outer end of said metallic extension.

9. A high power electron emitter comprising an elongated solid metallic core rod having spaced annular projections thereon intermediate the ends, an emissive coating applied to said core between said projections, a helical heater element at one end of said core for heating said elongated rod by conduction, and a tubular metallic shield surrounding said heater element and connected to said rod.

10. A high power electron emitter comprising an elongated cylindrical metallic core rod, a helical heater element wound on one end of said core rod, a pair of flanged metallic rings mounted on an intermediate portion of said rod in spaced relation, said rings increasing the diameter of said rod, and an emissive coating applied on said rod between said rings to a depth equal to the thickness of said rings so that said coating is flush with said rings.

11. A high power electron emitter comprising a solid tungsten core of cylindrical contour, spaced metallic rings on said core, each having an outwardly extending flange portion determining the active boundaries of the emitter, a coating of emissive material deposited on said core between said rings, said core having an extension on one end for dissipating heat energy transmitted through said core, a second extension on said core, an insulated heater element surrounding said second extension, and a metallic shield enclosing said heater and second extension and embracing said core between said coating and heater element.

12. A high power electron emitter comprising a tubular member of low expansion metal, a tubular shield secured to one end of said member, an elongated solid cylindrical core rod having a portion extending within said shield and a greater portion extending beyond said shield, a heater element interposed between said shield and the portion of said core rod enclosed thereby, a pair of flanged rings spaced in opposed relation on said rod intermediate the ends of the exposed greater portion, and a coating of electron emissive material applied to said rod between said rings and having a thickness equal to the thickness of said rings.

13. A high power electron emitter comprising an elongated cylindrical core rod, an insulated heater element wound on one end of said rod, a cylindrical metallic shield enclosing said element and securing one end thereof between said rod and said shield, an extension tubular member of low expansion metal attached to a flared portion of said shield and coaxially surround-

ing the other end of said heater element, a pair of low expansion metallic rings spaced on said rod beyond said shield, and a coating of emissive material on said rod between said rings.

14. A high power electron emitter comprising a cylindrical refractory metallic solid rod of large mass, an emissive coating affixed to an intermediate portion thereof for the emission of electrons in a high temperature zone of the discharge path to an anode surface, and an insulated helical heater element mounted adjacent one end of said rod for longitudinal conduction of heating energy to said coating through said rod, the other end of said rod forming a heat radiation portion for dissipating heating energy from said coating, said heater and radiation portion being remote from said

high temperature zone within the anode surface.

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