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2

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ELECTRON GUN AND CATHODE HEATER ASSEMBLY THEREFOR

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This invention relates to electron guns and particularly to thermionic electron guns for use in beam tubes.

One of the industries most affected by advances in technology is the electronics industry. In this industry manufacturers have had to search diligently for innovations in product design which would not only improve the operation of their product, but which would also result in the lessening of the cost to manufacture the product. The industry has become so competitive that a few cents saved on the cost of manufacturing a component can mean the difference between the acceptance or rejection of bids submitted in Government contracts for the supply of large quantities of electron components.

Some of the considerations which face the electronics manufacturers are reduction in weight of their components due to the likelihood of inclusion of their electronic components in space vehicles and missiles where the weight factor is extremely important. Also critical in this application is the ability of the electronic component to withstand extremes in acceleration, shock, vibration, and temperature. Since reliability under these adverse conditions is a prime necessity, it has become the practice of electronic manufacturers to buy only the best quality materials available regardless of material costs. Since these quality materials are expensive, one method of effecting a saving in material costs is to use a minimum number of parts arranged for maximum efficiency. It is therefore an object of the invention to provide a thermionic electron gun in which the elements of the gun are arranged to cooperate in a manner providing a rigid but light construction having the desired thermal characteristics for maximum efficiency.

Because reliability is a prime consideration, and because many of the parts used in electronic components are extremely small, much hand assembly has heretofore had to be done in the manufacture of electron tubes. The labor cost for the assembly of electron tubes is therefore no small factor in the ultimate cost to the consumer of these devices. It is therefore another object of the invention to provide an electron gun in which the elements lend themselves to being mass produced, and assembled using assembly line techniques which minimize labor expenditures.

In environments where electron tubes are accessible, it is desirable that the tube be designed to permit replacement of defective parts. This is particularly true with regard to those parts of an electron gun, for instance, which are noted for their short life, such as the heater and cathode of the electron gun. It is therefore a still further object of the invention to provide an electron gun in which the cathode and cathode heater coil may be easily removed and replaced and the envelope re-evacuated.

Because electron gun elements are enclosed in an evacuated envelope, and because they operate at very high temperatures, it is necessary that materials having a low vapor pressure be used. These materials, however, are expensive, and it is therefore another object of the invention to utilize materials having a somewhat higher vapor pressure and therefore lower cost, arranged in the vacuum envelope in a manner to preclude vaporization.

The invention possesses other objects and features of

advantage, some of which, with the foregoing, will become apparent from the following description and drawings which disclose one embodiment of the invention. It is to be understood that the invention is not limited to the embodiment described and chosen for illustration, as variant embodiments may be adopted within the scope of the appended claims.

Briefly described, the invention comprises a thermionic electron gun for use in an evacuated beam tube. The tube envelope hermetically encloses the gun elements, the main supporting element of the gun comprising a base plate having a cylindrical envelope portion integrally brazed thereto and extending away therefrom. The base plate also supports a focusing electrode, together with a heater coil and a cathode having a concave emitting surface adapted to project a beam of electrons axially through the envelope. A suitable radio frequency interaction structure is provided hermetically interposed between the electron gun and a collector forming the end of the envelope remote from the gun. Means are provided for rigidly supporting the cathode and cathode heater coil in an efficient heat exchanging relationship within the cylindrical envelope portion attached to the base plate. Terminals supported on the base plate exterior of the envelope are provided with conductive means extending into the envelope and electrically connected to the focus electrode and cathode-heater assembly.

Referring to the drawings:

FIGURE 1 is an elevational view illustrating a beam tube with the electron gun attached thereto.

FIGURE 2 is a vertical half-sectional view of the electron gun of my invention.

FIGURE 1 is shown greatly reduced in scale with a portion omitted to reduce its length. FIGURE 2 is shown approximately actual size.

In more specific terms, and referring to the drawings, the electron gun designated generally by the numeral 2 is integrally united in a composite beam tube structure including RF interaction section 3 and a collector 4. The gun comprises a base plate 5, fabricated preferably from copper, and provided adjacent its outer periphery on one flat side thereof with an annular groove 6. On the same side of the base plate are provided a plurality of circumferentially spaced recesses each adapted to receive a short cylindrical copper post 7. The bottom end of each post is integrally brazed in a recess, while the upper end portion of the post is centrally bored and tapped to provide a means of attaching related structure. On the opposite side of the base plate, a plurality of recesses 8 are provided at circumferentially spaced intervals, and provide a means of seating copper posts 9 which extend perpendicularly to the base plate and are provided with a central bore 12 useful in the attachment of associated circuit elements (not shown) to the base plate. Apertures 13 formed in the base plate provide a means of passing conductors through the base plate for connection to the electrode elements within the envelope.

Associated with each of the peripheral grooves 6 in the base plate is a cylindrical ceramic wall section 14 sealed at one end to the base plate by means of an annular sealing ring 16 hermetically brazed adjacent its inner periphery to the metalized end of the ceramic cylinder 14. A portion of the sealing ring 16 adjacent its outer periphery is integrally brazed or Heliarc welded to the outer end portion of a complementary cylindrical flange 17. The other end portion of the cylindrical flange 17 is brazed or otherwise integrally and hermetically joined to the base plate adjacent its outer periphery, this union being conveniently made by extending the flange into the groove 6 where it is joined to one of the sides thereof. An annular ceramic backing ring 18 brazed adjacent the inner peripheral portion of the sealing ring 16 on

the side thereof opposite the cylindrical ceramic section 14, prevents the build-up of stresses in the hermetic union, occasioned by fluctuations of temperature, from rupturing the union between the sealing flange 16 and the cylindrical section 14. The bottom surface 19 of the backing ring abuts the bottom of the groove 6 in the base plate and provides for relative sliding movement between the backing ring and the base plate due to variations in temperature. It will thus be apparent that one end of the cylindrical ceramic section 14 is integrally and hermetically brazed adjacent the outer periphery of the base plate. The nature of this union will also make apparent that the integrally joined edges 21 of sealing flanges 16 and 17 may be ground or cut off in order to open the envelope should this become necessary. For this reason it is preferred that the edges of the flanges be Heliarc welded rather than brazed.

Rigidly and conductively mounted on the base plate, and coaxially arranged with respect to the cylindrical dielectric wall section 14, is a cathode and cathode heater assembly. The cathode and cathode heater assembly is detachably but rigidly mounted on the base plate by means of screws 22 extending through the radially extending flange 23 of the cathode and heater assembly support ring which includes cylindrically extending flange 24. Because of its rigidity, the assembly ring is preferably fabricated from "Kovar," which is very strong and particularly adapted for use in environments such as this where relatively large diameters and thin cross sections are used. Brazed or spot welded about the cylindrically extending flange 24 is the lower end portion of a cylindrical molybdenum support cylinder 26. The upper end portion of the cylindrical support 26 is brazed or spot welded to the lower end portion of a cathode assembly support cylinder 27, preferably fabricated from nickel and provided at its upper end with a reduced cross-section portion 28 spot welded to the upper end portion of an apertured nickel cathode support cylinder 29. The cathode support cylinder 29 is integrally brazed or spot welded adjacent its upper end to the outer periphery of the cathode 31, which is provided with an emissive coating on its concave surface 32, and provided also with a central aperture 33 for purposes which will subsequently be described.

The nickel cathode support cylinder 29 extends downwardly from the cathode in coaxial arrangement with the support cylinder 27. The lower end of the cathode support cylinder 29 is provided with an inwardly or radially extending flange 34 adapted to underlie and to be spot welded or otherwise integrally secured to the outer peripheral edge portion of dish-shaped molybdenum heat reflector 36. Apertures 63-A in the support cylinder 29 prevent the entrapment of air molecules in the chamber so formed. As shown in FIGURE 2, a second dish-shaped molybdenum heat reflector 37 lies within the chamber and superimposed above the heat reflector 36, but axially spaced therefrom a distance determined by the height of dimples 38. The molybdenum heat reflector 37 therefore functions both to reflect heat toward the cathode area, and also functions as a spacer between the molybdenum heat reflector 36 and still another axially spaced heat reflector 39. The dish-shaped heat reflector 39 is provided adjacent its outer periphery with portions or tabs 41 struck from the material of the shield and projecting axially therefrom to provide spacing elements to space the reflector 39 from yet another dish-shaped molybdenum shield 42 which closely underlies the windings of a heater coil 43. The heater coil is provided with a non-conductive coating as is well known in the art, and is pressed into conformation with the concave surface of the heater shield 42 by means of an apertured molybdenum coil plate 44. The heater windings are preferably fabricated from tungsten wire, and the coil plate 44 is supported adjacent its central portion by an axially extending molybdenum pillar 46. The pillar 46 is preferably fabricated from tubular stock, and is provided adjacent one end with integral

tabs 47 struck from the tube and spot welded to the concave surface of plate 44. At its other end the pillar or hollow receptacle 46 is abutted against the bottom surface of the cathode about the central aperture therein. In order that this union may be free from vibration, the edge of the aperture in the cathode is conveniently rabbeted, and the upper end of the pillar fits snugly into the rabbet, with the inner diameter of the aperture being substantially equal to the inner diameter of the hollow pillar. Reverse ion bombardment which would normally impinge on the cathode is thus channeled into the pillar where the ions impinge and are trapped on the central portion of plate 44 and the interior of the hollow pillar 46.

Confined between the outer peripheral portion of the plate 44 and the bottom convex surface of the cathode, is a cylindrical molybdenum heat reflector 48. With dimples 49 formed in the cylindrical shield, it also functions as a spacer interposed between the cathode cylinder 29 and an inner heat reflector 50 formed from molybdenum. The latter reflector is coaxially arranged within the cylindrical reflector 48 and the cathode support cylinder 29 and is confined between the convex bottom surface of the cathode and the upper concave surface of the heater plate 44. It will thus be seen that the cathode and cathode heater assembly comprising cathode support cylinder 29, cathode 31, heat reflectors 36, 37, and 39, heat shield 42, heater coil, and molybdenum heater plate 44 are rigidly interrelated with the coaxially arranged molybdenum pillar or spacer 46 and the cylindrical reflectors 48 and 50. Such a cooperative relationship of elements lends itself to fabrication by mass production techniques, and results in an assembly which is inherently rigid. Additionally, the relationship of the elements is particularly adapted to prevent the radiation of heat away from the cathode in both an axial and a transverse direction. Such conservation of heat makes possible use of lower power in the heater coil, and thus results in a saving in the operation of the tube. It also lends itself to assembly as a composite unit which may later be adequately supported within the gun structure by being spot welded to the upper end of the cathode assembly support cylinder 27.

To further ensure against the radiation of heat in a direction away from the cathode, another molybdenum heat shield 51 is integrally secured within the cathode assembly support cylinder 27 intermediate its ends. This shield is also preferably concave and is axially spaced from the reflector 36. A peripheral edge portion of the shield 51 is supported at circumferentially spaced intervals on nickel tabs 52 spot welded to the cylindrical wall of the assembly support cylinder 27. Supporting the peripheral edge portion of the molybdenum heat shield at spaced intervals around the periphery lessens the conductive effect of the tabs and reduces the amount of heat that is dissipated by conduction into the assembly support cylinder 27. The tabs also function to accommodate slight displacement between the parts due to thermal expansion and contraction, and thus prevent distortion of the parts. Because of its low vapor pressure the molybdenum shield 51 is capable of withstanding the high temperatures which it will encounter in its proximity to the heater coil assembly. In this position it will function to shield a further apertured heat shield 53 from the effects of the high temperature. The latter shield is preferably fabricated from copper to take advantage of its high coefficient of heat reflectivity in the infra-red spectrum, but because copper characteristically has a higher vapor pressure, it is located in a relatively low temperature zone. It is provided around its peripheral edge with a continuous support ring having one flange 54 brazed adjacent the peripheral edge of the copper shield and a cylindrical flange 56 brazed to the assembly support cylinder 27. It will thus be seen that the copper and molybdenum shields 51 and 53 function to support and rigidify and form the bottom of a recess in the assembly support cylinder 27 in the

5

nature of a well within which the previously assembled cathode-heater coil package is suspended.

Axially spaced below the cup shaped copper shield 53, and integrally brazed adjacent the upper end portion of the cylinder 26, are a plurality of radially extending and axially spaced flat heat shields 57, spaced apart by peripheral flanges 58. This group of heat shields function to further isolate the cathode-heater package from related structure to prevent the radiation of heat thereto. As shown in FIGURE 2, apertures 61 in the heat shields, and apertures 62 in the cylinder 26, provide for the escape of air molecules from within these chambers and prevent entrapment of air therein upon evacuation of the envelope. Aligned apertures 63 in the reflector 36 and shield 53 adjacent the outer peripheries thereof cooperate with appropriate apertures 63-A in the cylindrical support cylinder 29 to further ensure against the entrapment of air molecules.

To connect the heater coil into an energizing circuit, the heater coil is provided with leads 64 and 65, both of which extend through the aligned apertures in the shields in spaced relation thereto, the lead 64 being provided with a tab 66, one end of which is brazed or spot welded to the lead 64, and its other end spot welded to the inner surface of cylinder 27. Lead 65 is also provided with a connecting tab 67 connected at one end to the lead and at the other end to the upper end portion of a terminal rod 68. The tabs 66 and 67 are preferably fabricated from tantalum, which is capable of withstanding high temperatures, while the terminal lead 68 is fabricated from tungsten, which is also capable of withstanding high temperatures. The lower end of the terminal rod 68 is brazed to the upper end of a copper rod 69, the lower end of which is brazed into a nickel plug 71. The plug is on the opposite side of the base plate from the electrodes within the gun envelope, and constitutes an external terminal for the heater coil. The nickel plug is provided with a radially extending flange 72 which abuts an annular plate 73 formed from copper and which is integrally brazed to an annular copper sealing flange 74 at its outer periphery. The inner periphery of the annular sealing flange is integrally and hermetically brazed to one end of a short ceramic cylinder 76. A second ceramic cylinder 77 in the nature of a backing ring is brazed adjacent the inner periphery of the sealing flange 74 on the opposite side thereof from the cylinder 76, and cooperates with a second annular sealing flange 78 brazed adjacent its inner periphery to the opposite end of the ceramic cylinder 77. The outer periphery of the annular sealing flange 78 is integrally brazed in a rabbeted groove formed in the edge of aperture 13 in the base plate 2. A third short ceramic cylinder 79 is integrally brazed to sealing flange 78, and with the cylinders 76 and 77 rigidly supports the flanges, and seals the aperture 13 against atmospheric pressure. An appropriately tapped bore 81 in the nickel plug 71 provides a convenient means for connection of a lead to a source of electric power. From the foregoing it will be apparent that a very effective means has been provided for insulatingly yet rigidly extending a conductor through the vacuum wall of the envelope represented by the base plate 2, and it will also be obvious that materials having low vapor pressure and high cost have been reduced to a minimum and have been arranged closer to the source of heat, and that the arrangement is such that other materials having somewhat higher vapor pressure but being lower in cost have been utilized to a large extent.

Coaxially surrounding the cathode supporting sleeves 26 and 27 is a focus electrode supporting cylinder 82. The focusing electrode supporting structure comprises a supporting flange fabricated preferably from monel metal or stainless steel and includes a radially extending flange 83 and an integral cylindrically extending flange 84. The cylindrically extending flange 84 is spot welded to the lower end portion of the focus electrode cylinder 82, while the upper end of the cylinder 82 is flared in a portion

6

86, and spot welded to the peripheral surface portion 87 of the focus electrode, designated generally by the numeral 88. The focus electrode preferably has a truncated conical cross section, and is provided at its upper end with a cylindrical section 89, to which is integrally brazed an arcing shield or ring 91, the configuration of which prevents arcing between the focus electrode and related structure. The lower edge 92 of the focus electrode is positioned closely adjacent the outer peripheral portion of the cathode and thus functions to form the beam of electrons emitted by the cathode.

As shown in FIGURE 2 the radially extending flange 83 of the focus electrode supporting structure is sandwiched between annular dielectric wafers 93. The dielectric wafers function to mechanically support the focus electrode structure and to insulate it from the base plate. Screws 94 extending through the central apertures of the annular ceramic wafers and threaded into posts 7 brazed to the base plate securely mount the focus electrode on the base plate. It will thus be seen that the focus electrode is detachably supported on the base plate, and is provided with a rigid supporting base structure, to prevent the effects of vibration. It will also be apparent that the arrangement of parts lends itself to fabrication by assembly line techniques such as automatic machinery and self-aligning or self jiggling parts.

To electrically charge the focus electrode with an energizing potential, a terminal rod 96 extends through an aperture 13 in the base plate, and is hermetically supported and sealed thereto as was described with respect to the rod 69. Like parts have been correspondingly numbered. Integrally spot welded to the upper free end of the terminal rod 96 is a tantalum strip or tab 97, the free end of which is integrally spot welded to one end of a tantalum conductor 98. The other end of the conductor 98 is conductively connected to the focus electrode supporting structure by being spot welded to the radially extending flange 83. It will thus be seen that by connecting the nickel plug 71 associated with the terminal rod 96 to a source of electric energy the focus electrode may be electrostatically charged in order to perform its function of focusing or forming the electron beam.

As shown in FIGURE 2, the free end of the ceramic wall section 14 is provided with an integrally brazed sealing flange 99, adapted to be hermetically brazed to the associated envelope structure. The associated structure includes a connecting annular copper plate 101 integrally brazed to a cylindrical metallic envelope portion 102, preferably of copper and functioning as a corona shield, the upper end of which is integrally brazed to an accelerating anode 103, which includes a short drift tube section 104. The accelerating anode 103 is integrally and hermetically interposed between the copper corona shield 102 and an associated dielectric envelope portion 106 by appropriate sealing means 107.

From the foregoing it will be apparent that the elements of the electron gun are arranged in a relationship which is conducive of a maximum amount of cooperation between the various parts to efficiently re-radiate heat towards the cathode, and which also prevents the detrimental effects of vibration resulting from the particular application in which the gun is used. The cooperative combination also takes advantage of the cooperative relationships disclosed to permit utilization of less costly materials having higher vapor pressures in locations which conventionally require more costly materials having lower vapor pressures. By this means applicant has materially reduced the cost of materials utilized in the electron gun, and by designing the individual parts for facility of fabrication by automatic machinery, has further achieved a saving in the cost of labor of fabricating the electron gun. The electron gun may therefore be produced faster, at less cost to the consumer, with a measure of reliability of operation not before attained in electron guns of the prior art.

I claim:

1. In an electron tube having an evacuated envelope, an electron gun comprising a base plate constituting part of the evacuated envelope, a hollow metallic support cylinder detachably secured at one end to the base plate and extending into the envelope, an electron emitting assembly including electrically energizable indirect heating means supported on the end of the support cylinder remote from the base plate, an accelerating anode within the envelope operatively arranged adjacent the emitting surface of the cathode to attract electrons therefrom when the indirect heating means is energized, and heat reflector means suspended from the end of said cylinder remote from the base plate to reflect heat from said heating means toward the cathode.

2. In an electron tube having an evacuated envelope, an electron gun comprising a base plate constituting part of the evacuated envelope, a hollow metallic support cylinder detachably secured at one end to the base plate and extending into the envelope, an electron emitting assembly including an apertured cathode having an emitting surface and a non-emitting surface, cathode heating means axially spaced from said non-emitting surface, a hollow receptacle closed at one end and having an open end in registry with the aperture in the cathode, said electron emitting assembly being supported on the end of the support cylinder remote from the base plate, an accelerating anode within the envelope operatively arranged adjacent the emitting surface of the cathode, and heat reflector means associated with said cathode heating means to reflect heat toward the cathode.

3. In an electron tube having an evacuated envelope, an electron gun comprising a base plate constituting part of the evacuated envelope, a hollow metallic support cylinder detachably secured at one end to the base plate and extending into the envelope, a cathode supported on the end of the support cylinder remote from the base plate and having emitting and non-emitting surfaces, said non-emitting surface facing into the support cylinder, an electrically energizable heater coil within the support cylinder axially spaced from the non-emitting surface of the cathode, means depending from said end of the support cylinder remote from the base plate and retaining the heater coil in said support cylinder, means interposed between the coil and the cathode for retaining the heater in said spaced relation to the cathode, and an anode within the envelope operatively arranged adjacent the emitting surface of said cathode to attract electrons therefrom when said heater coil is energized.

4. In an electron tube having an evacuated envelope, an electron gun including an indirectly heatable cathode and heating means therefor, and heat reflector means associated with said cathode and heating means and including a cylindrical heat reflector arranged to reflect transversely radiated heat toward the cathode and a dish-shaped heat reflector arranged to reflect axially radiated heat toward the cathode, said cylindrical and dish-shaped heat reflectors defining with said cathode a hollow chamber enclosing said heating means, means radially spaced about said hollow chamber for supporting said cathode, heating means and heat reflector means on said evacuated envelope, and an electron accelerating anode within the envelope operatively associated with said cathode.

5. A cathode-heater assembly for electron tubes comprising a cathode having a peripheral edge radially spaced about a central axis, a cylindrical heat reflector integral at one end with the peripheral edge of the cathode, a transversely extending reflector closing the other end of the cylindrical heat reflector, a cathode heater coil interposed

between the cathode and the transversely extending reflector and energizable to heat the cathode, and means interposed between the coil and the cathode and between the coil and the transverse reflector to support the coil and reflect heat therefrom toward the cathode.

6. A cathode-heater assembly for electron tubes comprising a cathode having a peripheral edge radially spaced about a central axis, a cylindrical heat reflector integral at one end with the peripheral edge of the cathode, a transversely extending reflector closing the other end of the cylindrical heat reflector, a cathode heater coil interposed between the cathode and the transversely extending reflector and energizable to heat the cathode, cylindrical spacer means coaxially arranged within the cylindrical reflector and interposed between the coil and the cathode to retain the coil axially spaced from the cathode, and spacer means interposed between the transverse reflector and the coil to retain the coil axially spaced from the transverse reflector.

7. The combination according to claim 6, in which said cylindrical spacer means include a cylindrical shell coaxially arranged adjacent said cylindrical reflector and a cylindrical pillar coaxially arranged adjacent the central axis of the assembly.

8. The combination according to claim 6, in which said spacer means interposed between the transverse reflector and the coil comprise a transversely extending dimpled spacer plate, a second plate parallel to said spacer plate and axially spaced therefrom by said dimples and having integral axially extending peripheral tabs thereon, and a transverse reflector plate supported on said tabs in spaced relation to said second plate and abutting the side of said coil remote from the cathode.

9. The combination according to claim 7, in which the cathode is centrally apertured and the cylindrical pillar is hollow and is provided with at least one open end registering with the aperture in the cathode.

10. The combination according to claim 7, in which said cathode is dish-shaped to provide a concave emissive surface and a convex non-emissive surface, and means are interposed between said cylindrical spacer means and the coil to effect conformation of the coil with the convex surface of the cathode.

11. In an electron tube having an evacuated envelope including axially aligned cylindrical dielectric and metallic portions, an electron gun comprising a base plate constituting part of the evacuated envelope and closing one end of the dielectric envelope portion, a hollow metallic support cylinder detachably secured at one end to the base plate and extending into the envelope, an electron emitting assembly including electrically energizable indirect heating means supported on the end of the support cylinder remote from the base plate, an accelerating anode within the envelope supported on the cylindrical metallic portion thereof and operatively arranged adjacent the emitting surface of the cathode to attract electrons therefrom when the indirect heating means is energized, and heat reflector means suspended from the end of said cylinder remote from the base plate to reflect heat from said heating means toward the cathode.

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