Oct. 13, 1953 H. D. DOOLITTLE ET AL 2,655,614

ELECTRON TUBE

Filed May 25, 1950

Fig. 1

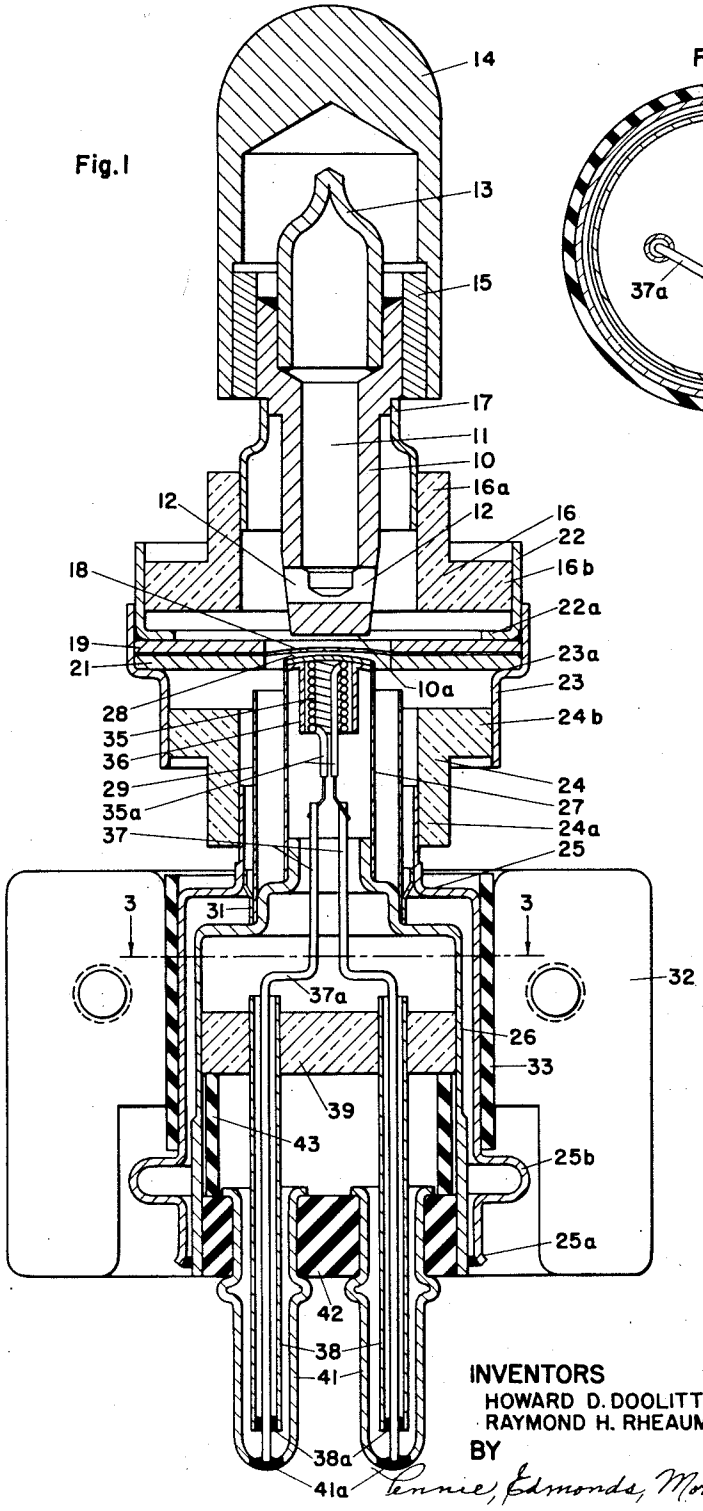


Fig. 3

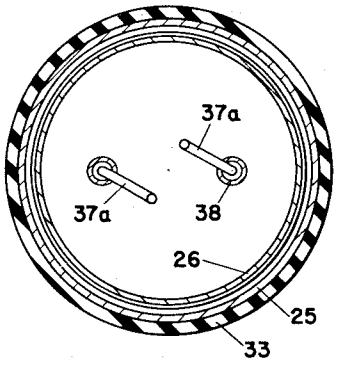


Fig. 4

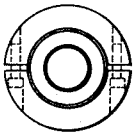


Fig. 2

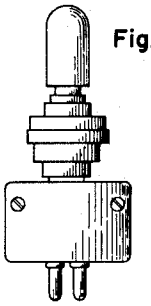
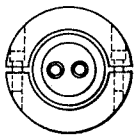


Fig. 5



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ELECTRON TUBE

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13 Claims. (Cl. 313—249)

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This invention relates to electron tubes, particularly to tubes for use in the ultra-high frequency or microwave region.

At the present time great emphasis is being placed on the development of apparatus for use in the ultra-high frequency or microwave portions of the radio frequency spectrum. While great progress has been made, the non-availability of suitable tubes often imposes serious restrictions on further development. In particular, it has become increasingly desirable to provide a small tube requiring relatively low input driving power and capable of driving larger tubes. While the broad principles of design of such tubes are fairly well known, the detailed design and construction has presented a major problem to tube engineers.

In general, such tubes require very small elements, very small spacing between elements, and close tolerances. Furthermore, the internal structure of the tube and the terminals must be arranged for use in ultra-high frequency circuits which usually take the form of tuned coaxial lines or cavities. It is important in the design and construction of such tubes to minimize the amount of inductance in the leads and connections, to minimize the amount of capacitance introduced by the connections to the active areas of the tube electrodes, and to minimize resistance and dielectric losses.

Tubes available at the present time leave much to be desired in respect of one or more of these requirements. They also commonly employ intricately shaped components which are difficult and time consuming to assemble, and make it difficult to maintain the required accuracy in the spacing of the active electrodes.

It is a principal object of the present invention to provide a tube having electrical characteristics which make is suitable for operation in the microwave region, and which is composed of relatively simple structural elements which can be assembled with the requisite accuracy by the use of simple jigging equipment and fixtures. Although described specifically in connection with tubes of the triode type, certain features of the invention may also be applied to tubes having more electrodes.

The capacitance and resistance and dielectric losses between input terminals and between output terminals of ultra-high frequency tubes are important factors in determining the performance and limitations of the tube and associated circuits. In accordance with a specific embodiment of the present invention a tube is provided having substantially rotational symmetry in its R. F. (radio frequency) components. The grid support is relatively planar and its terminal members are relatively short. The cathode and anode support structures are essentially perpendicular to the plane of the grid and grid support structure, and their respective terminal and envelope portions are at opposite ends of the tube with the terminals remote from the grid members. Tubular connectors are employed for cathode, grid and anode terminal structures and inter-element annular dielectric members or insulators are employed having a special shape and construction which minimize interelectrode capacitance and dielectric loss, and also provide a high resistance. To this end, low loss annular dielectric members are formed with an outwardly extending flange at or near one end. One annular dielectric member is employed between cathode and grid connectors and one of the connectors is sealed to the rim of the flange while the other is sealed to the inner surface at the end opposite the flange. A similar construction is employed between the grid and anode connectors. Portions of the connectors and dielectric members preferably form part of the evacuated envelope of the tube.

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The portion of the cathode and anode connectors sealed to each dielectric member advantageously does not overlap the flange section thereof. By means of this construction, a relatively long dielectric path is provided between the conductors resulting in a relatively low capacitance therebetween. Also, the structure minimizes the amount of dielectric employed to yield the desired length of path, so that dielectric losses are reduced. Furthermore, due to the length of path between conductors, the voltage gradient existing during use is kept low and hence the possibility of voltage breakdown is reduced.

The annular dielectric members or insulators are simple in shape and can be held to close tolerances during manufacture so that tubes can be readily assembled with the necessary close tolerances in the spacing of the active electrodes. It is preferred to use a low-loss ceramic because of its satisfactory fabricating properties and excellent electrical characteristics. The use of such ceramics and the shape of the dielectric members increases the resistance between electrodes, thus increasing the available power gain when the tube is used with suitable resonant tuning cavities, etc. This will be understood from the general relationship that power gain is proportional to the product of the input and output shunt resonant resistances multiplied by the grid-plate transconductance.

Further features and advantages of the construction will be pointed out hereinafter in connection with the description of a specific embodiment of the invention.

A serious problem encountered in the design of small tubes is that of heat expansion, particularly in the heater leads. Due to the small over-

all size of the tube, the heater leads must be introduced into a relatively small volume, and the problems of expansion become relatively more serious than in larger constructions. Expansion of the various elements often is so severe as to cause bowing and shorting of the heater leads, crushing of the heater coil, and occasionally shorting between turns of the heater coil. In addition, if the heater leads are sealed directly into a ceramic or glass insulator, expansion may produce forces sufficient to crack the insulator.

In accordance with another feature of the present invention, the heater lead construction and support is made sufficiently flexible so that expansion due to heat will not result in the above difficulties. To this end the heater leads are introduced through respective small thin-walled tubes. The leads are sealed in respective tubes at one end thereof, and the tubes are sealed near the other ends thereof in an insulator forming part of the evacuated enclosure. It is found that small thin-walled tubing has sufficient resiliency to compensate for the expansion differential between tube and insulator, without cracking the insulator or breaking the seal. By axially separating the seals to the thin-walled tubing, added flexibility is secured and the location of the final seal between tube and lead is made quite accessible to the assembly worker. An additional advantage may be obtained by making the thin-walled tubing of a metal whose coefficient of thermal expansion is at least as great as, and preferably greater than, the coefficient of expansion of the heater leads. For example, if the leads are made of molybdenum, thin-walled tubes of copper, nickel or nickel alloy may be employed with advantage. It is also desirable to employ transverse sections in the leads to increase flexibility, and these sections advantageously extend inwards toward opposite sides of the tube axis to minimize danger of short circuits. Further features and advantages of the heater assembly will be apparent from the following description.

The invention will be more fully understood by the following description of a specific embodiment thereof taken in conjunction with the drawings in which:

Fig. 1 is a greatly enlarged cross section of a specific embodiment of the invention, taken along the axis thereof;

Fig. 2 is an external view of the tube showing the actual size thereof;

Fig. 3 is a cross section taken along the line 3—3 of Fig. 1;

Fig. 4 is a top view of the tube of Fig. 2; and Fig. 5 is a bottom view thereof.

Referring to the drawings, an elongated anode 10 having an active electrode surface 10*a* is provided with an axial exhaust channel 11 terminating near the inner end in radial exhaust ports 12 within the evacuated envelope. Exhaust channel 11 is provided at the upper end with a sealoff 13 which may advantageously be made of metal. A cup-shaped anode terminal 14 fits over the sealoff 13 and the upper end of anode 10, and is sealed to the anode. While a direct seal may be employed if desired, in the specific embodiment shown a short thin cylinder 15 is inserted and tin soldered seals are employed between cylinder 15 and terminal 14, and between cylinder 15 and anode 10. The ring may advantageously be split for ease of assembly.

An annular ceramic insulator or dielectric member 16 is employed to join the anode structure to the grid structure. The member 16 has a cylindrical portion 16*a* and an outwardly extending flange portion 16*b*. The inner surface and outer flange surface are cylindrical. A metallic tubular conductor 17 is sealed at its upper end to anode 10 and at its lower end to the inner surface of the cylindrical portion 16*a* of the ceramic member. Conductor 17 forms part of the evacuated envelope of the tube and preferably does not overlap the flange section 16*b*.

A perforated grid 18 is held between two conductive disks 19 and 21. While the grid structure may be formed as desired, it advantageously is given a slight curvature as shown in Fig. 1, and may be formed by electro-deposition. Disks 19 and 21 are held between a tubular conductor 22 having an inwardly-turned flange 22*a* and a tubular conductor 23 having a shoulder 23*a*. Conductors 22 and 23 are sealed together to form a vacuum-tight connection which rigidly supports the grid structure and also provides an external terminal for the grid. Conductor 22 is sealed to the outer edge of flange 16*b* of the ceramic insulator, and preferably extends a short distance above the flange. Advantageously the seals to the insulator of conductor 22 and the anode conductor 17 are arranged in non-overlapping relationship.

Due to the form of ceramic insulator 16 and the manner of connecting grid and anode conductors thereto a relatively long dielectric path is provided between the two conductors which decreases capacitance therebetween. The length of path likewise provides increased resistance between the conductors and hence reduces the shunt resonant resistance between grid and anode conductors when the tube is used in a resonant circuit. By using flange 16*b*, unnecessary dielectric material above the flange is eliminated and hence dielectric losses are reduced.

By extending terminal 22 slightly above flange 16*b* the danger of voltage breakdown is reduced, and concentration of flux between the upper edge of terminal 22 and the ceramic flange is avoided, thereby further reducing dielectric losses.

An annular ceramic dielectric member or insulator 24, similar to 16, is employed to join the grid and cathode structures. To this end ceramic insulator 24 is provided with a cylindrical portion 24*a* and an outwardly extending flange portion 24*b*. Cylindrical conductor 23, forming part of the grid support and terminal structure, is sealed to the flange 24*b* and preferably extends slightly below the lower edge of the flange for reasons above given. The lower cylindrical portion 24*a* is joined to a coaxial tubular conductor 25 forming part of the cathode support and terminal structure, as well as a portion of the evacuated envelope. Conductor 25 is sealed at its lower end 25*a* to tubular conductor 26. A tubular foil member 27 is joined to the upper end of 26, the latter being reduced in diameter as shown. The indirectly heated cathode 28 is secured to the upper end of tubular foil 27. Tubular foil 27 is advantageously of low heat conductivity but good electrical conductivity. A tubular metallic shield 29 is advantageously provided in order to prevent the deposit of cathode coating material on the adjacent portion of ceramic insulator 24 during processing of the tube or during subsequent use. In this manner the high resistance of the ceramic material is not impaired by a surface coating of cathode material. Shield 29 is secured to a shoulder of conductor 26.

In order to allow precise spacing of cathode

and grid, which may be of the order of 0.002 inch in practice, the lower end of tube **26** makes a sliding fit with the lower end of tube **25**, and a folded section **25***b* is provided which may be compressed or expanded by external means to adjust the grid-cathode spacing. In order to shorten the path of current flow from cathode **28** to the outer terminal conductor **25**, an annular ring **31** may be affixed to tubular conductor **26** and make sliding contact with conductor **25**.

For convenience in inserting the tube into appropriate cavity arrangements, a large metal collar **32** may be secured to tube **25**. Collar **32** may advantageously be formed in two sections and bolted together, as shown in Fig. 5. On many occasions it is desired to D. C. insulate the cathode connection from the cathode, and to this end a thin cylinder **33** of dielectric may be interposed between collar **32** and tube **25**. This may advantageously be mica and should be made sufficiently thin to provide an effective radio frequency connection.

Turning now to the heater construction, a heater coil **35** is surrounded by a metal heat shield **36** affixed to the cathode **28**. The heater coil may be coated with alumina or other insulation to prevent shorting between turns, and the ends **35***a* are welded to heater leads **37**. Leads **37** pass through respective thin-walled metal tubes **38** and are vacuum sealed to the tubes at the lower ends thereof at **38***a*. Tubes **38** are vacuum sealed at or near their upper ends in the ceramic washer **39** which in turn is vacuum sealed to the inner surface of conductor **26**. Prongs **31** are mounted in an insulating disk **42** which in turn is secured in tube **26** by suitable means such as soft soldering. After assembly, the lower ends of leads **37** may be soldered to prongs **41** as shown at **41***a*.

As mentioned hereinbefore, heat expansion creates serious problems in the design of small tubes of this character. Leadin seals are likely to break, leads are likely to bow together and create a short circuit, and there is danger of creating sufficient pressure on the heater to crush it or cause turns to short circuit. By utilizing tubes **38**, the seal to ceramic washer **39** is highly effective, since the thin walls provide sufficient flexibility so that there is little or no danger of the seal being broken, or insulator **39** cracked. The separation between the seals to the insulator **39** and to the leads at **38***a* provides a considerable length of thin-walled tubing which gives substantial flexibility, and reduces the bowing of leads and danger of crushing the cathode.

It is also advantageous to make tubes **38** of a metal having a greater coefficient of expansion than leads **37** so as to at least partially compensate for expansion in the leads. If the coefficient of expansion of tubes **38** is sufficiently high, expansion may even be overcompensated, but such overcompensation is much less harmful than insufficient compensation or no compensation, inasmuch as tension on leads **37** would tend to separate them rather than cause them to short circuit, and slight pulling on the cathode heater can be tolerated.

However, to provide added flexibility, lateral sections **37***a* may be provided in the heater leads so that any net expansion or contraction will cause bending at these points and hence no deleterious effects. Indeed, bimetallic cross pieces may be employed so that upon heating they will tend to bow down to relieve some of the pressure on the heater. As an additional precaution, sections **37***a* may be made non-radial, so as to extend

inwardly toward opposite side of the axis, as shown in Fig. 3. Thus bowing will not tend to cause the upper axial portions of the heater leads **37** to move radially inwards and touch each other.

Ceramic washer **39** and prong support disk **42** are held in spaced position by a tubular member **43** of any suitable material such as a dielectric. The exact spacing of ceramic washer **39** may be changed from that illustrated if desired. In general it should be positioned so that there is a substantial length of leads **37** between the washer and the heater so as to allow flexibility. Also, it is desirable not to move it so close to the prongs as to sacrifice flexibility of tubes **38** or to endanger melting the seal at **25***a* when it is sealed in tube **26**, or vice versa. This last problem could of course be avoided by merging tubes **25** and **26** at **27**, and eliminating the lower portion of tube **25**. Such a modification would of course eliminate fold **25***b* which permits external adjustment of the cathode-grid spacing.

It will be noted that in the construction provided in accordance with the invention there is little danger of breaking the ceramic insulators **16** and **24** when the tube is handled and inserted or removed from cavities. Although the ceramic insulators form a portion of the evacuated envelope, they are largely protected by the grid tubular conductor formed by **22** and **23** so that with normal care no damage would occur to the tube.

It will be clear from the drawing and the foregoing description thereof that the component parts used in assembling the tube are simple in design and capable of being fabricated with ease and precision. Also it will be apparent that the parts may be assembled with the necessary precision by the use of relatively simple jigging equipment. Furthermore, the design and construction yields advantageous electrical characteristics which enable the tube to provide high gain even in the microwave region.

The features of the invention have been described in connection with a specific embodiment thereof. It will be apparent to those skilled in the art that many changes may be made in the details of design and construction within the spirit and scope of the invention. Also, some features may be employed and others omitted depending upon the particular application.

We claim:

1. An electron tube comprising cathode, grid and anode electrodes mounted in an evacuated chamber, substantially coaxially arranged tubular conductors attached to said electrodes respectively, at least a pair of said tubular conductors having open ends of different diameter extending toward each other in substantially non-overlapping relationship, an annular dielectric member of substantially cylindrical shape having an outwardly extending flange portion, one of said pair of tubular conductors being sealed to the inside of said dielectric member at the end thereof remote from said flange portion and the other of said pair being sealed to the outside of said flange portion, a heater for said cathode electrode and a pair of leads therefor extending through the cathode tubular conductor to the exterior of said evacuated chamber, and a pair of metallic support tubes surrounding a portion of said leads respectively and sealed toward the inner ends thereof in a wall of said evacuated chamber, said tubes being sealed toward the outer ends thereof to respective leads, the portions of said leads between the heater and the seals at the

outer ends of said tube being unrestrained against limited movement.

2. An electron tube comprising cathode, grid and anode electrodes mounted in an evacuated envelope, substantially coaxially arranged tubular conductors attached to said electrodes respectively and at least two of said conductors forming a portion of said evacuated envelope said two conductors being of larger diameter than the respective electrodes and having open ends of different diameter extending toward each other in substantially non-overlapping relationship with the plane of one open end adjacent the plane of the other open end, an annular dielectric member forming a portion of said envelope and having an outwardly extending flange section, the inner surface of said dielectric member being substantially cylindrical and of substantially uniform diameter and the outer flange surface being substantially cylindrical, one of said two conductors being sealed to said outer flange surface and the other being sealed to said inner surface of said dielectric member at the end thereof remote from the flange section, a heater for said cathode electrode and a pair of leads therefor extending through the cathode tubular conductor to the exterior of said envelope, and a pair of metallic support tubes surrounding a portion of said leads respectively and sealed toward the inner ends thereof in a wall of said envelope, said tubes being sealed toward the outer ends thereof to respective leads, the portions of said leads between the heater and the seals at the outer ends of said tubes being unrestrained against limited movement.

3. An ultra-high frequency electron tube comprising cathode, grid and anode electrodes mounted in an evacuated envelope, substantially coaxially arranged tubular conductors attached to said electrodes respectively and forming portions of said envelope, a pair of annular dielectic members on opposite sides of said grid forming portions of said envelope and each having an outwardly extending flange section at the end thereof toward the grid, said grid tubular conductor being sealed to the outer surfaces of respective flange sections and said cathode and anode tubular conductors being sealed to the inner surfaces of respective dielectric members in non-overlapping relationship with the respective flange sections, a laterally extending dielectric member sealed in said cathode conductor and a pair of axially extending metallic tubes sealed toward the inner ends thereof in the dielectric member, a heater for said cathode electrode and a pair of metallic conductive leads therefor extending through respective tubes to the exterior of said envelope, said leads being sealed in respective tubes toward the outer ends thereof.

4. An ultra-high frequency electron tube comprising laterally extending cathode, control grid and anode electrodes mounted in an evacuated envelope and spaced apart in an axial direction in the order named, substantially coaxially arranged tubular conductors attached to said electrodes respectively and forming portions of said envelope, a pair of annular ceramic dielectric members on opposite sides of said grid forming portions of said envelope and each having an outwardly extending flange section at the end thereof toward the grid, the inner surface and outer flange surface of each ceramic member being substantially cylindrical, said grid tubular conductor being sealed to said outer flange surfaces and projecting beyond the surfaces, said cathode

and anode conductors being sealed to the inner surfaces of respective ceramic members in non-overlapping relationship with the respective flange sections, a laterally extending dielectric member sealed in said cathode conductor and a pair of axially extending metallic tubes sealed toward the inner ends thereof in the dielectric member, a heater for said cathode electrode and a pair of metallic conductive leads therefor extending through respective tubes to the exterior of said envelope, said leads having a smaller coefficient of thermal expansion than said tubes and being sealed in respective tubes toward the outer ends thereof, and transverse sections in said leads near the inner ends of said tubes extending inwardly toward opposite sides of the axis and extending substantially axially between said transverse sections and said heater.

5. An electron tube comprising cathode, grid and anode electrodes mounted in an evacuated chamber, substantially coaxially arranged tubular conductors attached to said electrodes respectively, at least a pair of said tubular conductors having open ends of different diameter extending toward each other in substantially non-overlapping relationship, and an annular dielectric member of substantially cylindrical shape having an outwardly extending flange portion, one of said pair of tubular conductors being sealed to the outside of said dielectric member at the flange portion thereof and the other of said pair of tubular conductors being sealed to the inside of said dielectric member at the end thereof remote from said flange portion.

6. An electron tube comprising cathode, grid and anode electrodes mounted in an evacuated envelope, substantially coaxially arranged tubular conductors attached to said electrodes respectively and at least two of said conductors forming a portion of said evacuated envelope said two conductors being of larger diameter than the respective electrodes and having open ends of different diameter extending toward each other in substantially non-overlapping relationship with the plane of one open end adjacent the plane of the other open end, and an annular dielectric member forming a portion of said envelope and having an outwardly extending flange section, the inner surface of said dielectric member being substantially cylindrical and of substantially uniform diameter and the outer flange surface being substantially cylindrical, one of said two conductors being sealed to said inner surface of said dielectric member at the end thereof remote from the flange section and the other being sealed to the outer surface of said flange section.

7. An ultra-high frequency electron tube comprising cathode, grid and anode electrodes mounted in an evacuated envelope, substantially coaxially arranged tubular conductors attached to said electrodes respectively and forming portions of said envelope, the anode and cathode tubular conductors extending from opposite ends of the tube toward the grid tubular conductor, and a pair of annular dielectric members on opposite sides of said grid forming portions of said envelope and each having an outwardly extending flange section at the end thereof toward the grid, the cathode and anode tubular conductors being sealed to the inner surfaces of respective dielectric members in non-overlapping relationship with the respective flange sections and the grid tubular conductor being sealed to the outer surfaces of respective flange sections.

8. An ultra-high frequency electron tube com-

prising laterally extending cathode, control grid and anode electrodes mounted in an evacuated envelope and spaced apart in an axial direction in the order named, substantially coaxially arranged tubular conductors attached to said electrodes respectively and forming portions of said envelope, the anode and cathode tubular conductors being of smaller diameter than the grid tubular conductor and having respective open ends extending toward corresponding open ends of the grid tubular conductor from opposite sides of the grid and in substantially non-overlapping relationship therewith, the planes of the open ends of anode and cathode conductors being adjacent the planes of the open ends of the grid conductor respectively, and a pair of annular ceramic dielectric members on opposite sides of said grid forming portions of said envelope and each having an outwardly extending flange section at the end thereof toward the grid, the inner surface and outer flange surface of each ceramic member being substantially cylindrical and of substantially uniform diameter, said cathode and anode tubular conductors being sealed to the inner surfaces of respective ceramic members in non-overlapping relationship with the respective flange sections and said grid tubular conductor being sealed to the outer flange surfaces and projecting therebeyond.

9. An ultra-high frequency electron tube comprising laterally extending cathode, control grid and anode electrodes mounted in an evacuated envelope and spaced apart in an axial direction in the order named, a coaxial tubular grid terminal conductor attached to said grid and forming a portion of said envelope, said grid conductor having tubular open ends extending in opposite axial directions, anode and cathode terminals at respective ends of said tube having respective coaxial tubular conductors extending toward said grid conductor with open ends in non-overlapping relationship therewith and of smaller diameter, the planes of the open ends of anode and cathode conductors being adjacent the planes of the open ends of the grid conductor respectively, a pair of coaxial annular dielectric members forming portions of said envelope on each side of said grid and each having an enlarged flange at the end thereof toward the grid, said anode and cathode tubular conductors being sealed to the inner surfaces of the dielectric members respectively and the tubular ends of said grid conductor being sealed to the outer surfaces of the flanges thereof respectively.

10. An electron tube comprising cathode, grid and anode electrodes mounted in an evacuated chamber, substantially coaxially arranged tubular conductors attached to said electrodes respectively, a heater for said cathode electrode and a pair of leads therefor extending through the cathode tubular conductor to the exterior of said evacuated chamber, and a pair of metallic supports tubes surrounding a portion of said leads respectively and sealed toward the inner ends thereof in a wall of said evacuated chamber, said tubes being sealed toward the outer ends thereof to respective leads, the portions of said leads between the heater and the seals at the outer ends of said tubes being unrestrained against limited movement.

11. An electron tube comprising cathode, grid and anode electrodes mounted in an evacuated envelope, substantially coaxially arranged tubular conductors attached to said electrodes respectively, a laterally extending dielectric member sealed in said cathode conductor and a pair of axially extending metallic tubes sealed toward the inner ends thereof in the dielectric member, a heater for said cathode electrode and a pair of metallic conductive leads therefor extending through respective tubes to the exterior of said envelope, said leads being sealed in respective tubes toward the outer ends thereof.

12. An ultra-high frequency electron tube comprising laterally extending cathode, control grid and anode electrodes mounted in an evacuated envelope and spaced apart in an axial direction in the order named, substantially coaxially arranged grid and anode terminal conductors, a substantially coaxially arranged cathode tubular conductor extending from the cathode to the adjacent end of the electron tube, a laterally extending dielectric member sealed in said cathode conductor intermediate the cathode and said adjacent end, a pair of axially extending metallic tubes sealed toward the inner ends thereof in said dielectric member, a heater for said cathode electrode and a pair of metallic conductive leads therefor extending through respective tubes to the exterior of said envelope and sealed in respective tubes toward the outer ends thereof, and transverse sections in said leads near the inner ends of said tubes extending inwardly toward opposite sides of the axis and extending substantially axially between said transverse sections and said heater.

13. An ultra-high frequency electron tube comprising laterally extending cathode, control grid and anode electrodes mounted in an evacuated envelope and spaced apart in an axial direction in the order named, substantially coaxially arranged grid and anode terminal conductors, a substantially coaxially arranged cathode tubular conductor extending from the cathode to the adjacent end of the electron tube, a laterally extending dielectric member sealed in said cathode conductor intermediate the cathode and said adjacent end, a pair of axially extending metallic tubes sealed toward the inner ends thereof in said dielectric member, a heater for said cathode electrode and a pair of metallic conductive leads therefor extending through respective tubes to the exterior of said envelope, said leads having a smaller coefficient of thermal expansion than said tubes and being sealed in respective tubes toward the outer ends thereof, and transverse sections in said leads near the inner ends of said tubes extending inwardly toward opposite sides of the axis and extending substantially axially between said transverse sections and said heater.

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