

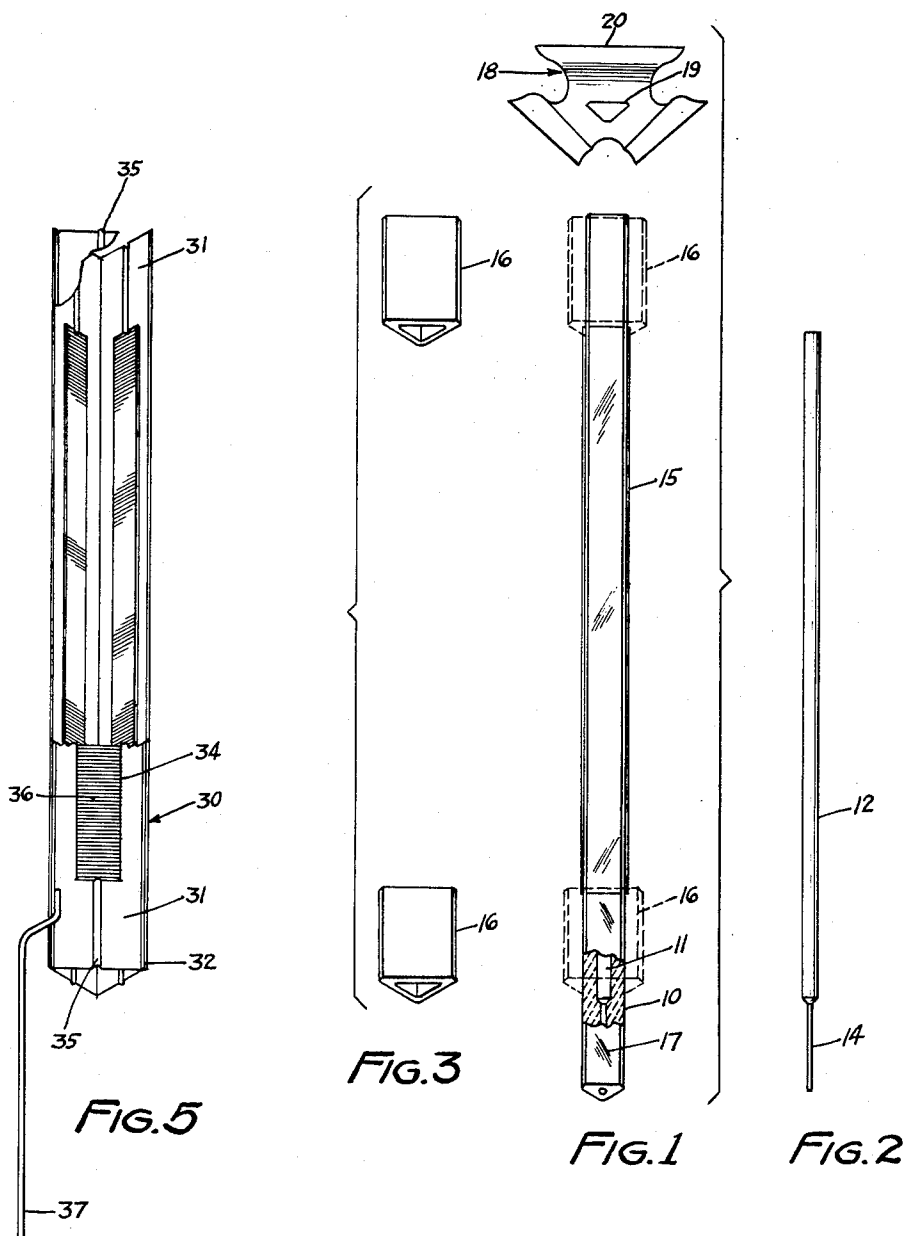
April 12, 1960

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VACUUM TUBE

2,932,759

Filed July 21, 1954

5 Sheets-Sheet 1



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5 Sheets-Sheet 2

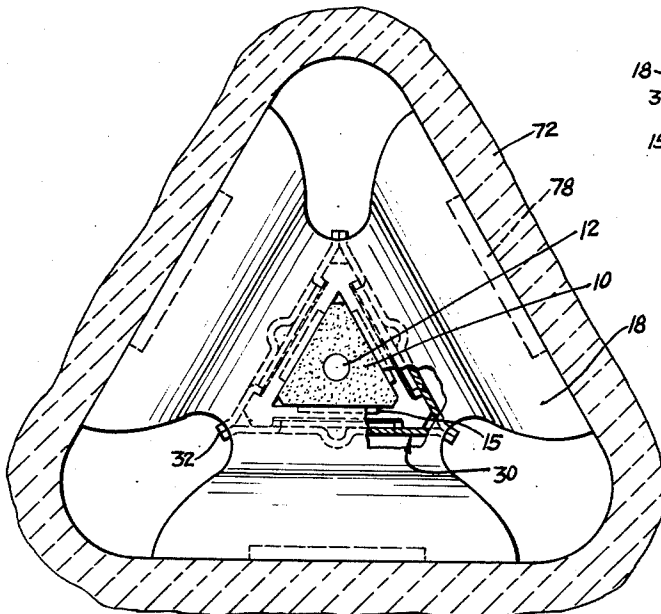


FIG. 17

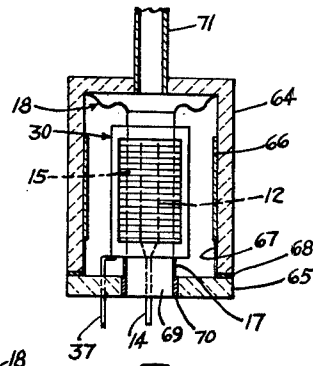


FIG. 13

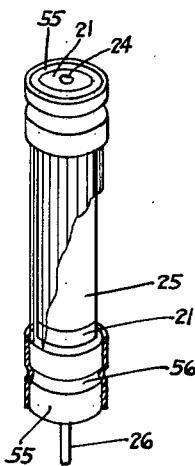


FIG. 11

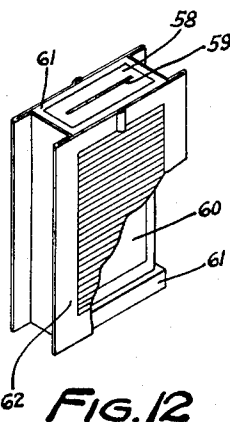


FIG. 12

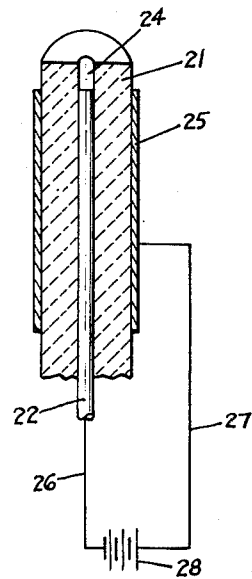


FIG. 4

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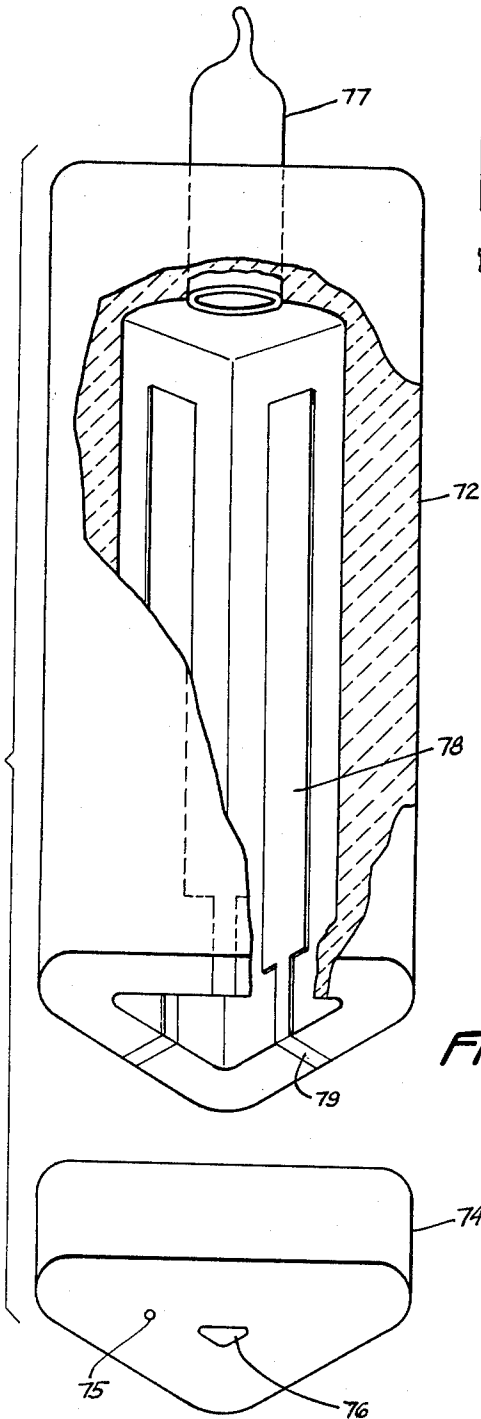


FIG. 14

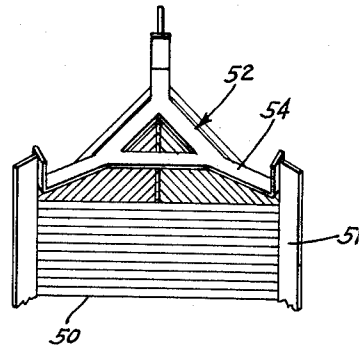
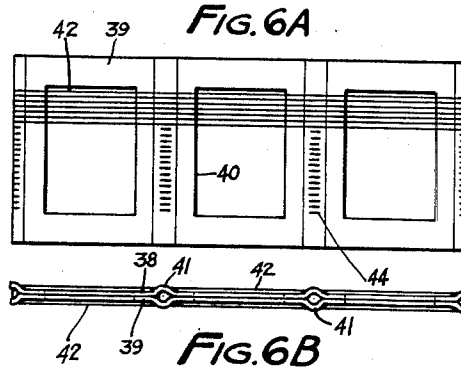


FIG. 9

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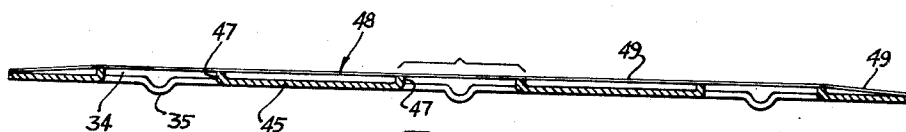


FIG. 8

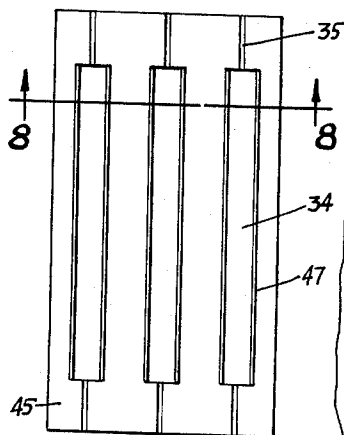


FIG. 7

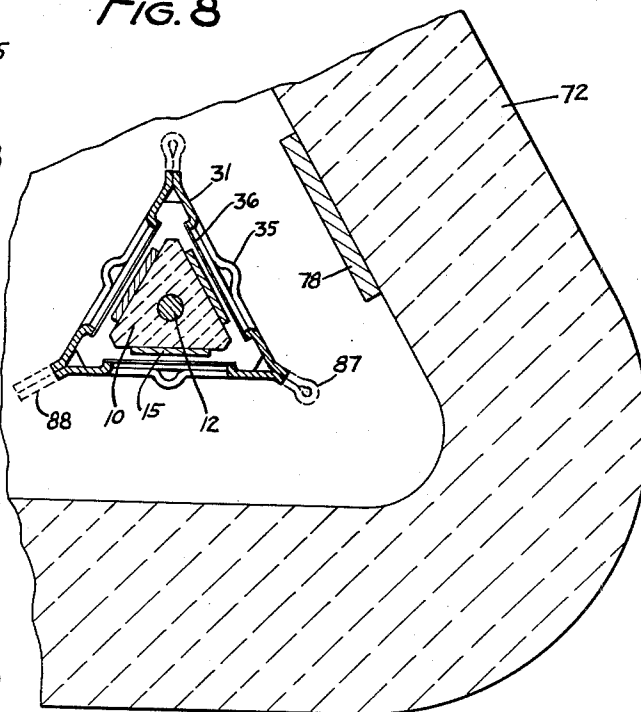


FIG. 18

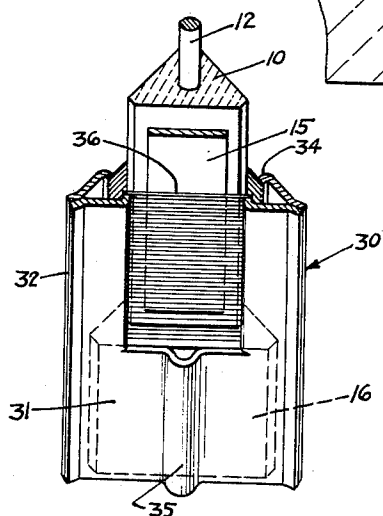


FIG. 10

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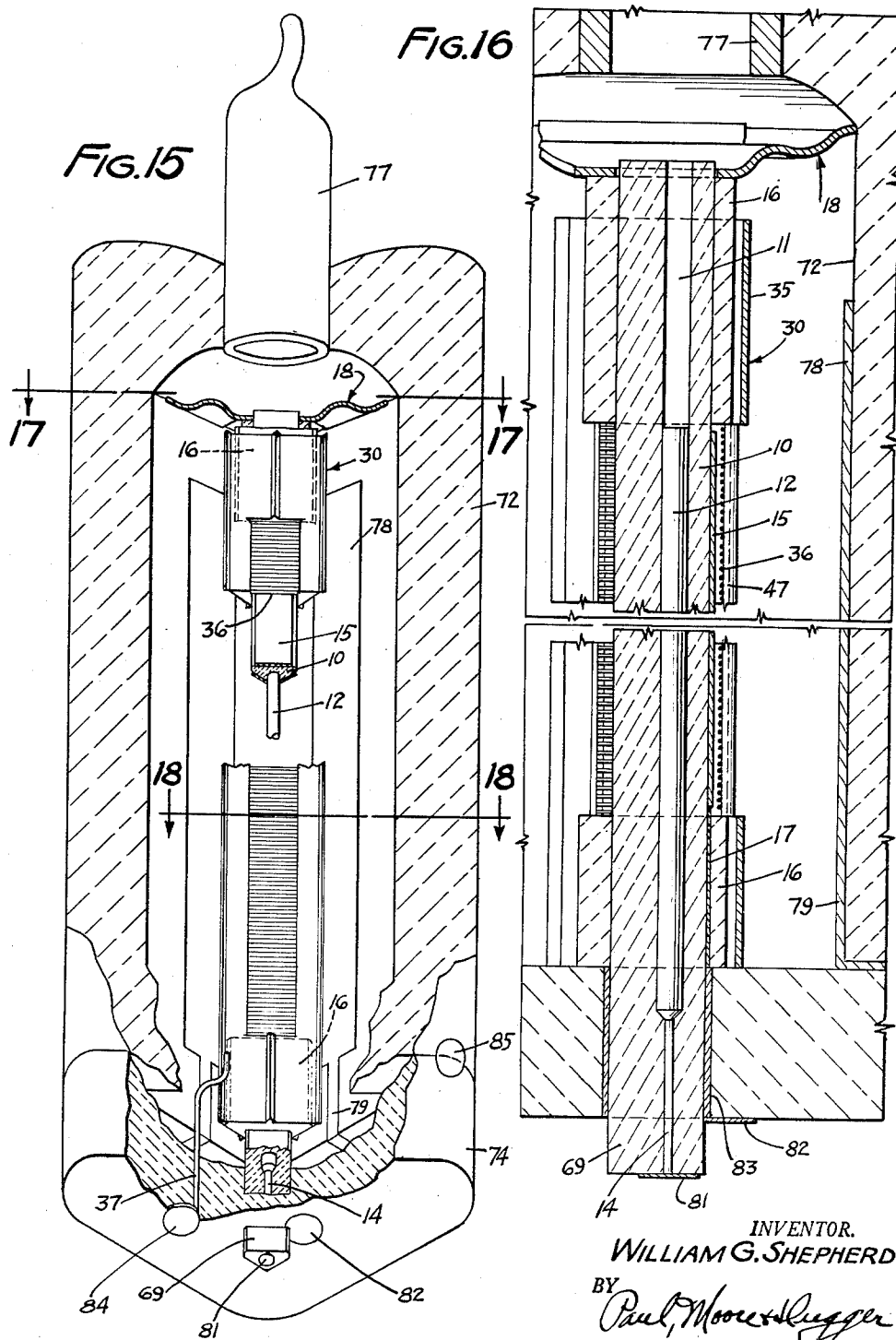
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5 Sheets-Sheet 5



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VACUUM TUBE

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Application July 21, 1954, Serial No. 444,773

11 Claims. (Cl. 313—337)

This invention relates to vacuum tubes for use in electronic circuits and to improved vacuum tube construction and manufacture. More particularly the invention relates to strong rugged vacuum tubes which are resistant to shock and which are substantially free from internal vibration, and to methods of making such tubes.

Conventional vacuum tube structures now in use employ metallic heater elements. These elements are made of wire, usually tungsten, wound into configurations such as double helices or spirals or simply folded. The formed wire is usually coated with an insulating material which is fired into a hard coating. This heater element is inserted into a cathode sleeve, generally of nickel, which carries an electron emitting coating upon its outer surface. The internal heater is heated by the passage of current and by radiation heats the electron emissive coating. The radiation from the internal heater is determined by its thermal emissivity radiating area and by its temperature. Because the surface area of the heater is generally much smaller than the surface area of the surrounding cathode sleeve it is necessary to operate the heater at temperatures considerably in excess of the temperature of the emitting sleeve. Any break in the heater wire results in total failure of the tube. Any break in the insulating coating of the heater wire may result in partial shorting between individual turns of the wire or between the wire and the cathode sleeve. Because the heater is usually supported by rather long leads to a base stem and by the frictional forces between the heater and cathode sleeve it is usually subject to motion within the tube. Motion of individual elements within a tube not only increases their susceptibility to damage and subsequent failure but also sets up harmonics due to vibration of the parts which influence the performance of the vacuum tube.

A closely related problem is that arising in the construction of non-microphonic vacuum tubes because of relative movement between the cathode and the control grid. Conventional grids presently in use are usually wound on two parallel rod supports. The grid wires are usually wound spirally on a mandrel holding the support rods. A cathode is inserted coaxially within the grid, the spacing between grid and cathode being determined by the shape of the mandrel upon which the grid is wound. The grid and cathode are supported by being inserted into mica spacers at each end. Any deformation of the cathode or the grid results in deviations from the design characteristics of the tube. The nature of this arrangement of grid and cathode necessarily prevents any tension on the grid wires so that they may vibrate individually. Moreover, the section of the cathode itself is not structurally strong, but may be deformed by mishandling.

The principal object of this invention is to provide a vacuum tube having an improved ceramic heater, cathode and grid construction and methods of making such tubes.

Another object of this invention is to provide improved rugged vacuum tube construction whereby the tube is

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resistant to shock and substantially free from internal vibration.

It is another object of this invention to provide a ceramic heating element and cathode for an electronic vacuum tube and a method of making such an electrode structure.

Still another object of this invention is to provide a new frame grid construction and method of making same.

Other objects of the invention will become apparent as the description proceeds.

To the accomplishment of the foregoing and related ends, this invention then comprises the features hereinafter fully described and particularly pointed out in the claims, the following description setting forth in detail certain illustrative embodiments of the invention, these being indicative, however, of but a few of the various ways in which the principles of the invention may be employed.

The invention is illustrated by means of the drawings in which the same numerals refer to corresponding parts and in which:

Figures 1, 2 and 3 are perspective elevations of the several components making up the heater element and cathode of this invention;

Figure 4 is a vertical sectional elevation of another embodiment of the heater element and cathode;

Figure 5 is a perspective elevation of one form of grid construction according to this invention;

Figure 6A is a plan view of one form of construction of the grid;

Figure 6B is an end elevation of the grid material of Figure 6A;

Figure 7 is a plan view of another form of grid construction;

Figure 8 is a vertical section taken along line 8—8 and in the direction of the arrows of Figure 7;

Figure 9 is a top perspective view of tension means for one form of grid;

Figure 10 is a fragmentary perspective view of a ceramic heater and cathode set in place within the grid structure;

Figures 11 and 12 are alternative forms of grid and cathode construction;

Figure 13 is a simplified assembly embodying a heater, cathode and a grid formed according to this invention;

Figure 14 is an exploded perspective view, partly broken away, of a vacuum tube body;

Figure 15 is a perspective view, partly broken away, of a complete vacuum tube constructed according to this invention;

Figure 16 is an enlarged vertical section through the tube of Figure 15;

Figure 17 is a transverse section through the vacuum tube taken along the line 17—17 and in the direction of the arrows of Figure 15; and

Figure 18 is a similar section taken along the line 18—18 and in the direction of the arrows of Figure 15.

Referring now to the drawings and particularly to Figures 1 to 4, there is here shown in detail the construction of the ceramic heater and cathode structure. As shown in Figure 1 the structure comprises a heater body 10 having a central portion formed of a conductive ceramic material, such as a high alumina body impregnated with metal. For example, the body may be the type designated AI 200 manufactured by the Coors Porcelain Company of Golden, Colorado. At least the lower end of the ceramic body is non-conducting. The ceramic heating element 10 may be formed in sections and bonded together. For example, non-conducting ceramic end sections may be bonded to a central metal impregnated conducting section. Heater body 10 has a central aperture 11 running throughout its length into which a metal

conductor 12 may be fitted and bonded to the conductive portion of the ceramic body. Conductor 12 may be a solid rod or may desirably be tubular and is provided with a connecting lead-in wire 14.

The cathode structure includes a metal sleeve or areas of deposited metal or metal plates 15 bonded to the central portion of the outer surfaces of the ceramic heater body, the plates carrying electron emitting coating on their outer surfaces. This metal may be nickel, for example. The cathode structure is supported in part by means of insulating ceramic spacer sleeve 16 at either end of the heating portion of the cathode. Sleeves 16 serve also to locate and support the grid structure. The heater body 10 is preferably conductive only in the area between the supporting sleeves 16. This is accomplished by impregnating only that area of the body with metal. The outer surfaces of the non-conductive portion of the ceramic body below the cathode plates 15 are coated with metal to make connection between the cathode and the external surface of a finished tube. A spider 18 formed of some spring-like metal provides lateral support for the upper end of the cathode body with flexibility for differential expansion. The top end of the body 10 fits into an aperture 19 in the spider. Edges 20 are adapted to urge against the inside surfaces of the ceramic bulb of the vacuum tube.

The triangular form of construction shown in Figures 1, 2 and 3 is just one of several which may be used. Alternatively a round rod-like ceramic body 21 having a heating conductor element 22 in aperture 24 may be used as shown in Figure 4. The electron emitting cathode 25 is here in the form of a metal sleeve bonded to body 21 and having an electron emitting coating at its outer surface. The heater element 22 and sleeve 25 are connected by means of conductors 26 and 27 to a current source 28. The cathode structure may be in planar form as shown in Figure 12.

In the cathode construction as illustrated the heating current flows radially outwardly through the ceramic body and the joule heating raises the temperature of the body. It will be recognized that even though the ceramic body may crack either in a plane perpendicular to the axis of the body or in a plane passing through the axis no interruption in current flow will result. Because of the greater area of the heating element lower heater temperatures are required. The resistance of the heater is large so that high voltage-low current heat source can be used. Because the end sections of the heater can be made non-conducting and since the ceramic body has some thermal impedance it becomes possible to support the heater by the ceramic body itself, thereby providing a sturdy structure resistant to shock and mechanical vibration.

One form of control grid is shown in Figure 5. The grid is preferably made in triangular form since this is the strongest grid section which can be readily adapted to a coaxial type of electron tube. This form of construction permits tensioning of the grid wires and produces a structurally strong grid, in addition to providing some spring or resiliency in the frame so that the grid wires will be continuously under tension. The grid 30 is formed of three frames or panels 31 joined at their edges 32. The panels are formed of a thin strong electrically conductive metal such as molybdenum. The grid is of a size to form a tight sliding fit with sleeves 16. Each panel is provided with an opening or window 34 corresponding in size and shape with the electron emitting plate 15 on the ceramic heater element. Each panel is provided with a corrugation 35 to give it added strength, and to tension the grid wires. The tensioned grid wires 36 are stretched across the openings 34 of each panel. A lead-in conductor 37 is provided to make connection with an external contact. Grid wires 36 are preferably formed of tungsten or similar metal.

One method of forming the grid structure is shown in

Figures 6A and 6B. Two metal sheets 38 and 39, each having windows or openings 40 punched through their surfaces and having corrugations 41 at the edges of the grid panels are laid face to face. The grid wire 42 is then wrapped tightly around and around the pair of sheets across the openings and are brazed to the corrugations or swaged into notches 44 formed in the corrugations. Thereafter, the sheets are separated and formed into the desired grid structure.

Another and preferred method of forming the grid is shown in Figures 7 and 8. As shown here, a sheet 45, from which the structure of Figure 5 is formed, has a plurality of openings or windows 34 punched with a swage cut leaving projecting edges 47 on one surface. The sheet is also provided with corrugations 35 for the purpose of providing some spring tension in the grid. The projecting edges are provided with notches to receive the grid wires. Two of these sheets are laid face to face with the swage cuts uppermost and the fine grid wire 48 is wound tightly around and around the sheets in the notches and across the openings 34. Thereafter the wires are swaged into the notches and the sheets are separated and formed into grid structures. The edges of the grid panels are brazed or spot welded and the excess of the metal sheet may be cut away. The excess wire 49 may be removed if desired leaving only lateral grid wires 36 in place in either of these forms of construction.

Instead of forming the grid structure with rigid frames around the openings it may be desirable to cut away the top and bottom portions of the frames. As shown in Figure 9 the grid then comprises the lateral grid wires 50 held between strips 51 of sheet metal brazed or spot welded together. The grid wires are held under positive tension by means of a spring spider 52 formed in the general configuration of a cross-section of the grid (triangular as shown) and having a plurality of spring arms 54 to urge outwardly against the metal strips 51 and hold the grid wires 50 under tension.

Figure 10 shows a fragment of the ceramic heater element located and positioned within the grid structure held in position by means of insulating ceramic sleeve 16.

In Figure 11 there is shown an alternative form of cathode in which the grid laterals are parallel to the axis simultaneously making possible a true coaxial structure with an optimum ratio of transconductance to capacitance. In constructing this form of cathode the cathode base is round and as in Figure 4 comprises a conductive ceramic body 21 surrounded over part of its surface by metal sleeve 25. An internal heating element is in aperture 24 heated by current from conductor 26. The cathode body is provided with a round ceramic sleeve 55 at both ends. The grid may be formed by winding by either of the described methods or by any similar method. The top and bottom frame members are cut away and a grid section having a width corresponding to the circumference of round insulating sleeves 55 is cut, wrapped around the cathode base and sleeves 55 and crimped into grooves 56 in the sleeves. Alternatively, the grid can be formed by pressing two frame portions around opposite sides of the cathode base, welding the resulting projecting pair of wings, cutting away the excess metal and crimping the grid structure into grooves 56. The expansion of the ceramic body during heating serves to tension the grid wires.

A plane-parallel cathode structure is shown in Figure 12. Here, the ceramic heater body 58 and the center conductor 59 of the heater are rectangular in cross-section. The opposed surfaces of the body 58 each have a cathode plate 60 bonded to the ceramic base. A non-conducting ceramic sleeve 61 at each end of the ceramic body 58 positions and supports grid structure 62. It is apparent that a cathode structure of square cross-section may similarly be made.

A simplified assembly embodying the grid structure and cathode heater of this invention is shown in Figure

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13. The grid and heater are as heretofore described. These structures are enclosed within a ceramic envelope 64 brazed to a ceramic stem 65. An anode 66 is formed by a metal sheet bonded to the inside surface of the envelope or by metal deposited on the inside of the envelope. A conductive coating 67 forms a connection between plate 66 and brazed joint 68 which provides connection outside the envelope. The lower end 69 of the ceramic heater is non-conducting with a conductive coating 17 on its outer surface. The brazed joint 70 between the ceramic stem 65 and the lower end of the ceramic heater body provides connection to cathode plates 15. A metallic tubulation 71 brazed into the top of the envelope is provided for drawing a vacuum and sealing off the tube.

In Figure 14 there is shown a ceramic envelope body specifically adapted to receive a triangular cathode structure. The tube body comprises a thick rugged triangular ceramic envelope 72 and a triangular ceramic stem or base 74. Stem 74 is provided with an opening 75 for the grid conductor 37 and a larger opening 76 for the non-conducting base of the ceramic heater body. The envelope has a tubulation 77 brazed in its top. Plates 78 formed of metal sheet bonded to the inside surfaces of the envelope have a narrow depending portion 79 which lead out between the envelope and the base to make outside contact.

Figures 15, 16, 17 and 18 show views of a completed strong rugged vacuum tube constructed according to this invention. Metalized patch contact 81 provides the electrical connection for the heater element and contact 82 provides connection through brazing seal 83 conductive coating 17 with the cathode. Contact 84 connects to the grid structure and side contacts 85 provide outside connection for the plates 78. In Figure 18 there is shown in dotted lines the portions 87 and 88, formed by the folds of the sheet from which the grid structure is made, which may be cut off after the panel portions 31 of the grid structure have been welded or brazed together.

In the finished vacuum tube the cathode grid assembly becomes an integral part of the ceramic envelope. This is accomplished by the extension of the ceramic heater through and brazed to the stem. The tube is strong and rugged. It is resistant to shock. But, even if the ceramic heater element should become cracked, because it is conductive throughout the heating area and the cathode is bonded to the heater, it will continue to function. Because the internal structure of the tube is substantially rigid there is substantially no relative motion between the cathode and the control grid and virtually no vibration of the grid wires. The grid construction of this invention, besides being strong, permits tensioning of the grid wires.

It is to be understood that the applicability of the grid structure of this invention is not limited to use with the ceramic heater. On the contrary such control grids may be used in conjunction with cathodes and heaters of conventional design and construction.

As many apparently widely different embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that I do not limit myself to the specific embodiments herein.

What I claim is:

1. An electrode structure for electronic vacuum tubes comprising a ceramic heater element, said ceramic element being electrically conductive throughout part of its length and non-conductive throughout the rest of its length, a conductive heating element within said ceramic element, a metal cathode bonded to the outer surface of the ceramic element adjacent the conductive portion thereof, conductor means for connecting said heater element to a current source and a conductive coating over the non-conductive portion of the ceramic element for connecting the cathode to a current source.

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2. An electrode structure for electronic vacuum tubes comprising a ceramic heater element, said ceramic element being impregnated with metal throughout part of its length to render it electrically conductive, the remainder of said ceramic element being non-conductive, a conductive heating element within said ceramic element and bonded to the conductive portion thereof, a wire conductor for connecting said heating element to a current source, a metal cathode bonded to the outer surface of the ceramic element adjacent the conductive portions thereof and a conductive coating over the non-conductive portion of the ceramic element for connecting the cathode to a current source.

3. An electrode structure for electronic vacuum tubes comprising an electrically conductive ceramic heater element, a conductor within said heater element, a metal cathode bonded to the outer surface of said heater element and means for connecting said heater element and said cathode to a source of electric current, insulating sleeves fitted on said ceramic heater element adjacent each end thereof and a control grid supported on said insulating sleeves spaced apart from said cathode, said grid comprising a metal frame surrounding said ceramic element, an opening in the frame opposite the cathode and fine substantially parallel grid wires extending across said opening.

4. An electrode structure for electronic vacuum tubes comprising a ceramic heater element, said ceramic element being electrically conductive throughout part of its length and non-conductive throughout the rest of its length, a conductive heating element within said ceramic element, a metal cathode bonded to the outer surface of the ceramic element adjacent the conductive portion thereof, conductor means for connecting said heater element to a current source and a conductive coating over the non-conductive portion of the ceramic element for connecting the cathode to a current source, insulating sleeves fitted on said ceramic heater element adjacent each end thereof and a control grid supported on said insulating sleeves spaced apart from said cathode, said grid comprising a metal frame surrounding said ceramic element, an opening in the frame opposite the cathode and fine substantially parallel grid wires extending across said opening.

5. An electrode structure for electronic vacuum tubes comprising a ceramic heater element, said ceramic element being impregnated with metal throughout part of its length to render it electrically conductive, the remainder of said ceramic element being non-conductive, a conductive heating element within said ceramic element and bonded to the conductive portion thereof, a wire conductor for connecting said heating element to a current source, a metal cathode bonded to the outer surface of the ceramic element adjacent the conductive portions thereof and a conductive coating over the non-conductive portion of the ceramic element for connecting the cathode to a current source, insulating sleeves fitted on said ceramic heater element adjacent each end thereof and a control grid supported on said insulating sleeves spaced apart from said cathode, said grid comprising a metal frame surrounding said ceramic element, an opening in the frame opposite the cathode and fine substantially parallel grid wires extending across said opening.

6. An electrode structure according to claim 5 further characterized in that the cross section of said ceramic heater element is triangular, each face surface of said ceramic element has a metal cathode bonded thereto and said control grid is triangular and coaxial with the ceramic element having an opening in each of the three panels opposite from and spaced apart from said cathodes.

7. An electrode structure for electronic vacuum tubes comprising a heater element and cathode, conductor means for connecting the heater element and the cathode to current sources, an insulating sleeve fitted on at least one end of said heater element and a control grid sup-

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ported on said insulating sleeve spaced apart from said cathode, said grid comprising a metal frame surrounding the heater element, an opening in the frame opposite the cathode surface and fine substantially parallel grid wires extending across said opening.

8. An electronic vacuum tube comprising a ceramic base structure and a ceramic envelope brazed thereto, said envelope enclosing an electrode structure comprising an electrically conductive ceramic heater element, a conductor within said heater element, a metal cathode bonded to the outer surface of said heater element and conductor means from the heater element and cathode extending through the ceramic base for connecting said heater element and said cathode to a source of electric current, insulating sleeves fitted on said ceramic heater element adjacent each end thereof and a control grid supported on said insulating sleeves spaced apart from said cathode, said grid comprising a metal frame surrounding said ceramic element, an opening in the frame opposite the cathode and fine substantially parallel grid wires extending across said opening, one end of said ceramic heater extending through the ceramic base and being brazed thereto, at least one plate bonded to the inner surface of said envelope and means connecting said plate to an external contact.

9. An electronic vacuum tube comprising a ceramic base structure and a ceramic envelope brazed thereto, said envelope enclosing an electrode structure comprising a ceramic heater element, said ceramic element being electrically conductive throughout part of its length and non-conductive throughout the rest of its length, a conductive heating element within said ceramic element, a metal cathode bonded to the outer surface of the ceramic element adjacent the conductive portion thereof, conductor means from the heater element extending through the ceramic base for connecting said heater element to a current source and a conductive coating over the non-conductive portion of the ceramic element for connecting the cathode to a current source, insulating sleeves fitted on said ceramic heater element adjacent each end thereof and a control grid supported on said insulating sleeves spaced apart from said cathode, said grid comprising a metal frame surrounding said ceramic element, an opening in the frame opposite the cathode and fine substantially parallel grid wires extending across said opening, one end of said ceramic heater extending through the ceramic base and being brazed thereto, at least one plate bonded to the inner surface of said envelope and means connecting said plate to an external contact.

10. An electronic vacuum tube comprising a ceramic base structure and a ceramic envelope brazed thereto, said envelope enclosing an electrode structure comprising a ceramic heater element, said ceramic element be-

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ing impregnated with metal throughout part of its length to render it electrically conductive, the remainder of said ceramic element being non-conductive, a conductive heating element within said ceramic element and bonded to the conductive portion thereof, a wire conductor extending from the heater element through the ceramic base for connecting said heating element to a current source, a metal cathode bonded to the outer surface of the ceramic element adjacent the conductive portions thereof and a conductive coating over the non-conductive portion of the ceramic element for connecting the cathode to a current source, insulating sleeves fitted on said ceramic heater element adjacent each end thereof and a control grid supported on said insulating sleeves spaced apart from said cathode, said grid comprising a metal frame surrounding said ceramic element, an opening in the frame opposite the cathode and fine substantially parallel grid wires extending across said opening, one end of said ceramic heater extending through the ceramic base and being brazed thereto, at least one plate bonded to the inner surface of said envelope and means connecting said plate to an external contact.

11. An electronic vacuum tube according to claim 10 further characterized in that the cross section of said ceramic heater element is triangular, each face surface of said ceramic element has a metal cathode bonded thereto and said control grid is triangular and coaxial with the ceramic element having an opening in each of the three panels opposite from and spaced apart from said cathodes.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,932,759

April 12, 1960

William G. Shepherd

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 8, line 34, list of references cited, under "UNITED STATES PATENTS", for the patent number "1,701,256" read
-- 1,701,356 --.

Signed and sealed this 13th day of September 1960.

(SEAL)

Attest:

KARL H. AXLINE

Attesting Officer

ROBERT C. WATSON
Commissioner of Patents