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3,034,009

PIN SEAL ACCELERATOR TUBES

Filed Jan. 18, 1960

4 Sheets-Sheet 1

FIG. 1

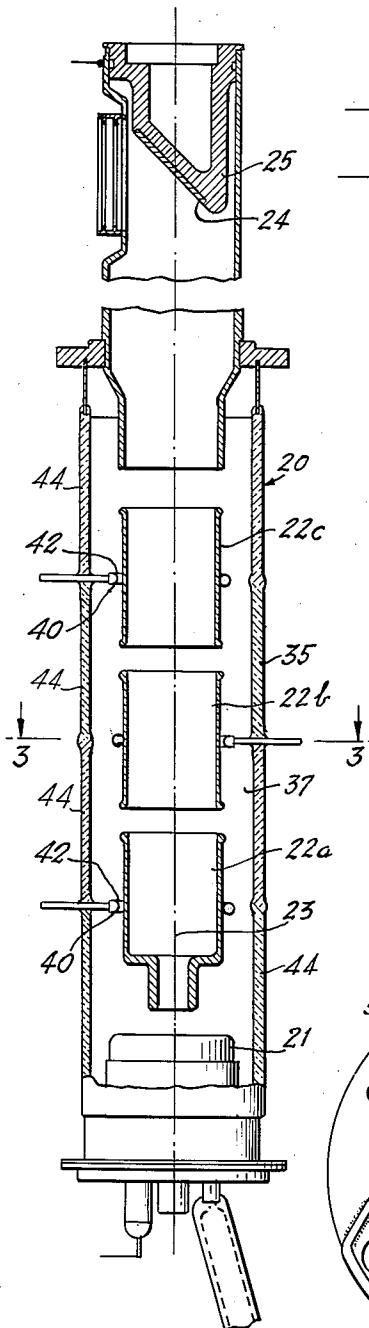


FIG. 1A

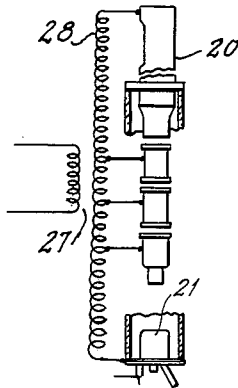


FIG. 2

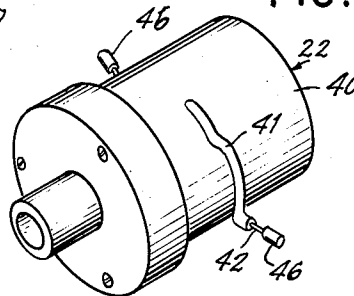


FIG. 3

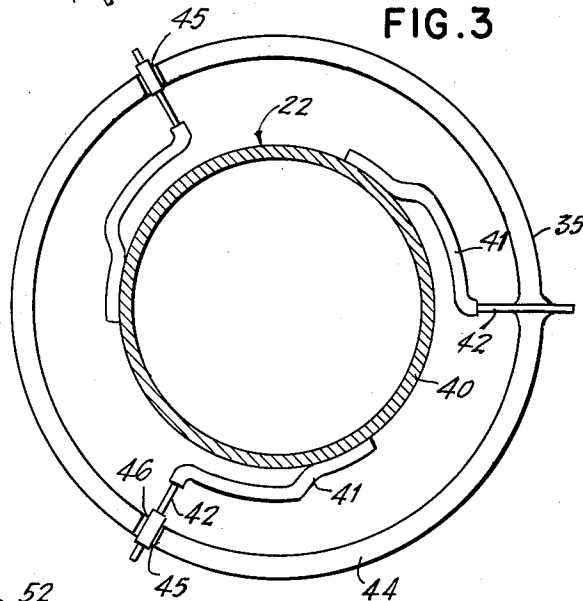
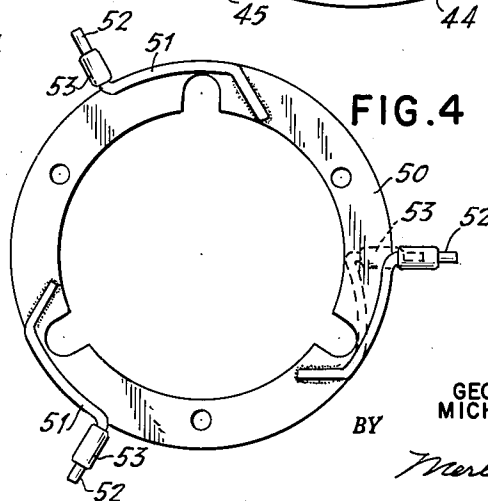


FIG. 4



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FIG.7

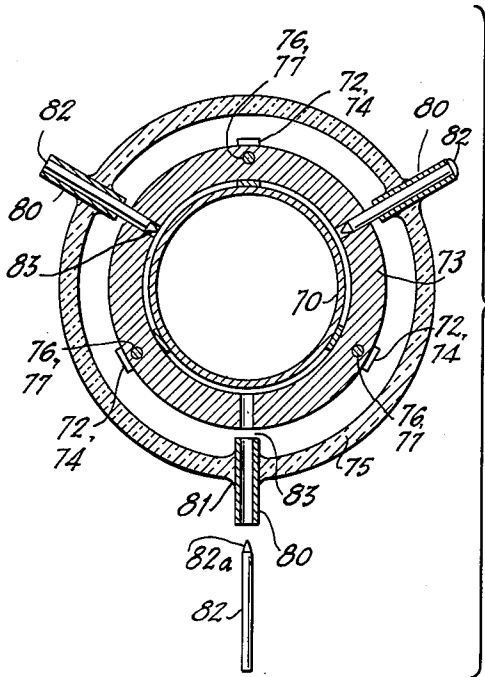
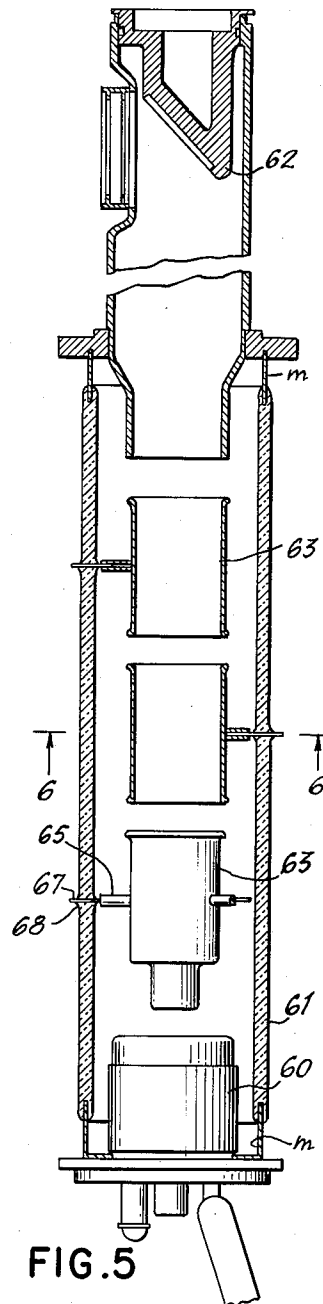
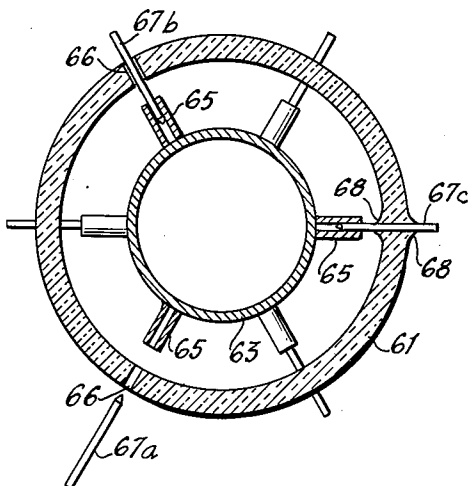


FIG.6



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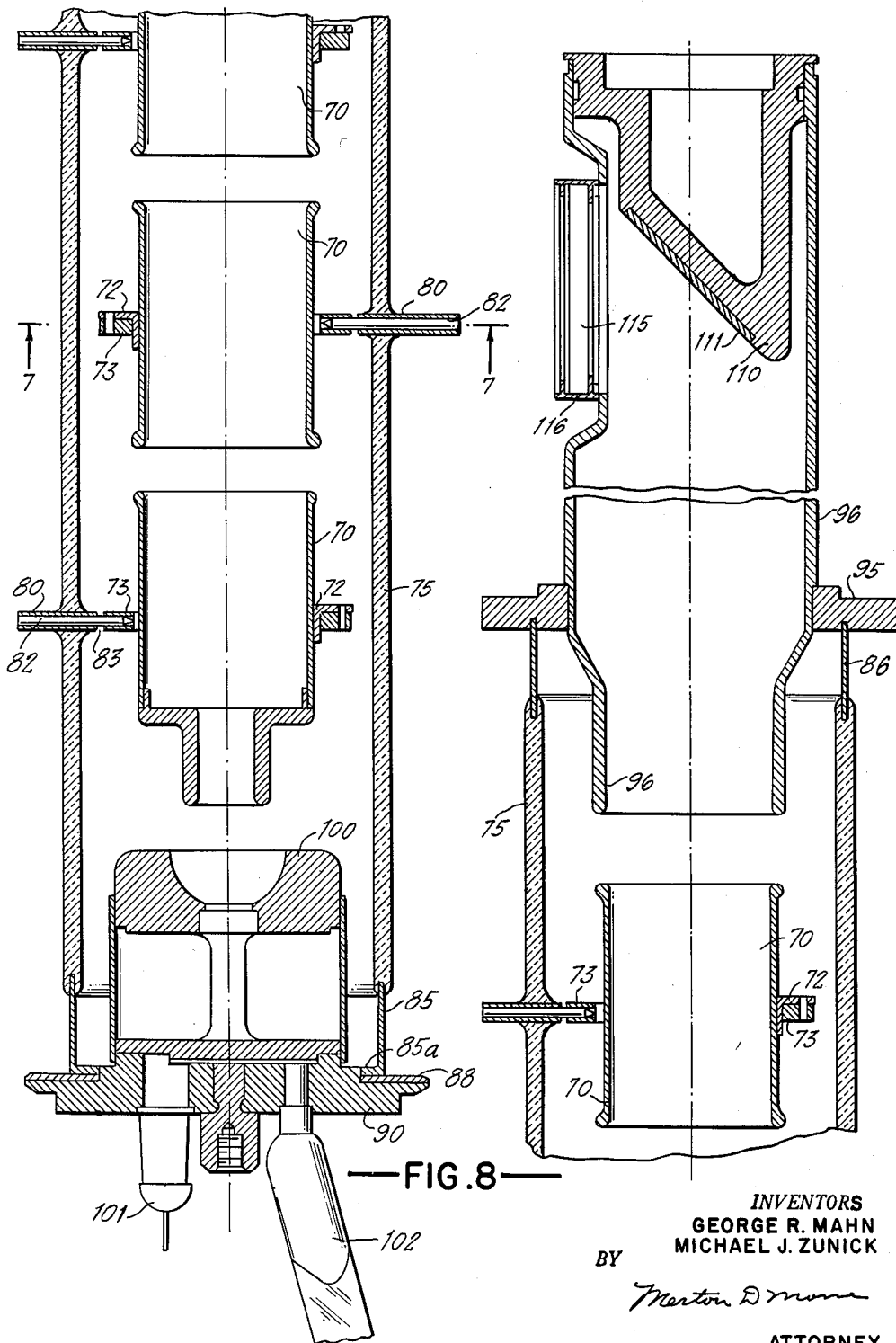
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FIG. 9

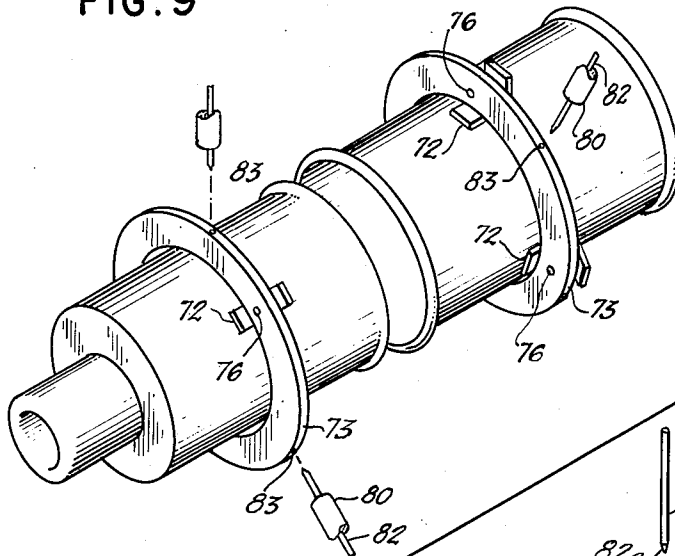
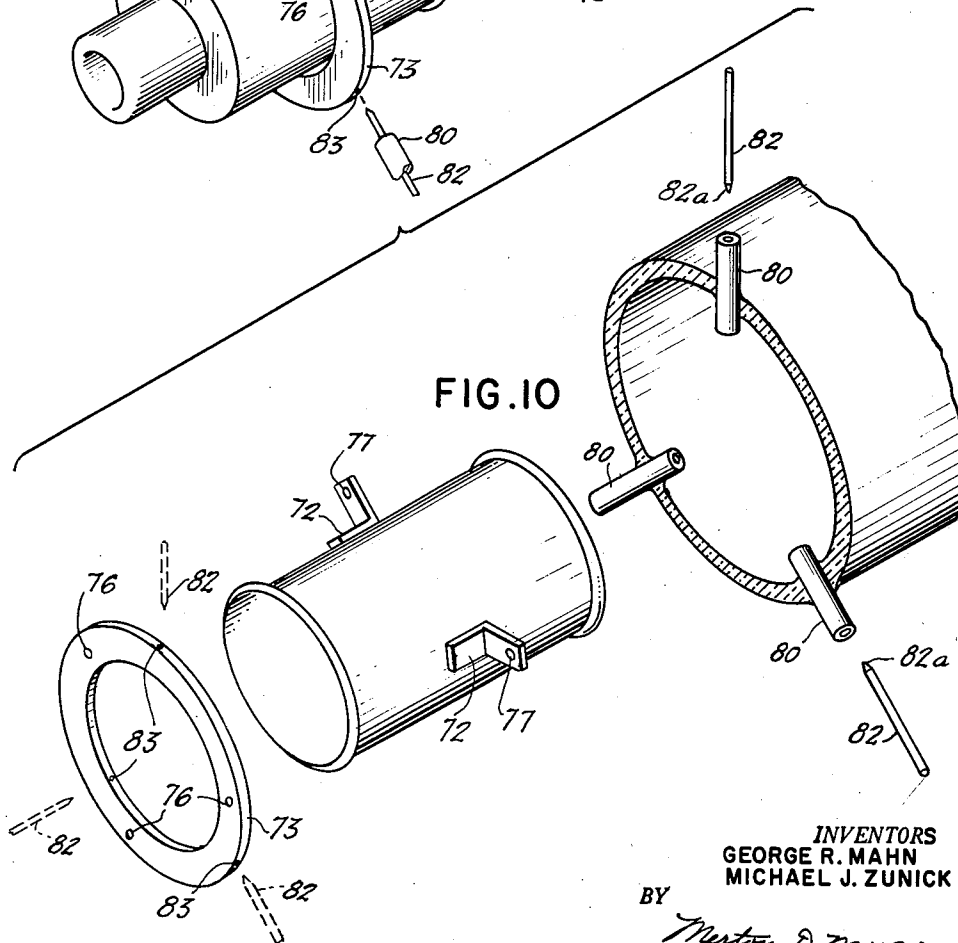


FIG. 10



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3,034,009

PIN SEAL ACCELERATOR TUBES

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12 Claims. (Cl. 313—85)

This invention relates to electron tube accelerator columns which are employed to control and to guide an electron beam emanating from a cathode and guided to a target plate or anode of the tube, and it relates particularly to novel control electrode assemblies and supports in such columns, which are generally elongated cylinders enclosing the cathode and the anode and the control electrodes disposed between them.

Such a column has general application in electron tubes in which the beam is to be controlled and shaped and guided along a predetermined path or axis between the cathode and the anode or target plate. The invention is disclosed and described herein as applied to an X-ray tube, but its features are applicable to tubes having electron permeable windows such as are used for electron irradiation and for cathode ray tubes, generally.

In such an electron tube in which an electron beam is generated and then controlled to engage a remote surface, one or more control electrodes are disposed in co-axial alignment to serve as an electron lens system that encircles a substantial part of the path or region through which the electron beam will travel.

Voltages are applied to the individual control electrodes as well as to the cathode and to the anode, in order to shape and guide and accelerate the electron stream from the cathode to the anode.

In applications of the present type it is desirable, in one form of control, to constrict the stream of electrons to a narrow beam in order to establish a high density beam at the point of impact on the target plate or anode of the tube, here particularly an X-ray tube. More generally, the electron lens system may be utilized to accelerate and focus the beam on a desired area, large or small, at the region of impact.

In order to establish such concentrating and guiding action on the electrons in the stream, the control electrodes are conventionally, but not necessarily, cylindrical in form. The several control electrodes are then disposed co-axially along the intended path of the electron beam, and are suitably spaced to establish the proper electric field for the desired concentrating and guiding action on the electron beam.

In such accelerating columns, as well as in X-ray tubes employing such control electrodes, the fundamental problem is how to dispose and locate the control electrodes to properly shape and guide the electron stream, and, as a corollary to that problem, how to support those control electrodes so they will remain in proper positions against the stresses that develop during operation.

In the conventional accelerating columns, heretofore made and employed for this purpose, especially in connection with X-ray tubes, each control electrode has embodied an inner cylindrical metallic electrode body and an outer concentric metallic cylindrical, or annular and cylindrical, support that has been joined with suitable supporting glass cylinders to constitute the final control column. The outer supporting metallic cylinders of the control electrodes and the separate cylinders of glass were essentially of the same diameter. The glass cylinders thus served as insulating spacers and supports for the metal electrodes. Spacing of the electrodes, of course, establishes the shape of the field alongside the electron beam path and thereby establishes and determines the

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guiding or shaping effect of that field on the stream of electrons.

The manufacture of such previous conventional accelerator columns involved many difficulties and problems. The shape and the disposition of each electrode contributed to the orientation and shape of the electric field between adjacent electrodes. The shape and disposition of the field in turn controlled the path of travel of the individual electrons in such manner as to shape the stream of electrons in order to form the desired beam.

In order to control the effect of the electrode fields on the stream of electrons for a symmetrical guiding effect, it is essential that the control electrodes are of proper dimensions and properly spaced and co-axially disposed. Thus, the outside diameter, the inside diameter and the radius of curvature of adjacent ends of the electrodes are important to establish the shape of the electrostatic field that will, in turn, shape the electron beam.

In such previous conventional accelerator columns the several control electrodes were each provided with an outer supporting cylinder relatively concentric with the control electrode. Those outer supporting cylinders were fused to and secured between the glass cylinders to make up the entire control column. The sealing of the supporting cylinder for each control electrode to the two neighboring glass cylinders required two glass-working operations of extremely high accuracy at the circle of contact between each circular end edge of the metallic supporting cylinder and its mating insulating and spacing glass cylinders. In such conventional structure the metal supporting cylinder is joined by an internal annular flange to its control electrode.

The difficulties and the extra efforts involved in manufacturing such previous conventional structure arose from the fact that two glass sealing operations were required between the supporting cylinder and the two adjacent glass cylindrical sections. Those sealing operations had to assure hermetic seals for the proper operation of the entire assembly in controlling the electron beam. The nature of such sealing operations to form a longer structure required that the glass cylinders be closely of the same diameters. Moreover, a high degree of skill and care were necessary.

The accelerating columns of that conventional type thus embodied many joined sections with considerable metal in the cylindrical supports between the intermediate cylindrical glass sections. The high temperatures needed for the sealing operations and the extra handling of the several sectional components makes it difficult to keep those sections completely clean during assembly. Moreover, some oxidation of the metal takes place and some gases become occluded in the heated metal. The final column, after complete assembly, must therefore be subjected to a special cleaning operation to eliminate any dirt, scale, metallic oxide and loose metal pieces that might have been admitted or formed during assembly. For safe operation at the high voltages used in these columns, the surfaces within the columns must be clean and free of occluded gases.

Thus, a particular type of construction may be completely adequate operatively, as an end result, but nevertheless, involve manufacturing operations that impose extra efforts or hazards against proper operative conditions in final assembly. Thus, one of the major cares that must be observed in manufacturing control columns is that they be clean inside and free of any foreign or unwanted materials or particles.

For example, one construction, otherwise operationally suitable, may be undesirable, because it does not lend itself to cleaning that is simple and that will assure clean surfaces upon completion of manufacture. Therefore,

the construction design may be good or bad according to how simple and effective the cleaning operations can or need be to assure a clean final construction.

An important feature of this invention is that the method of manufacture and assembly makes it easy to avoid contamination and makes the column easy to clean.

An important limitation of the method of forming a conventional column by joining alternate metal and glass cylinders to insulatingly support the control electrodes, is that such method or structure does not lend itself to reducing the length of a column for high voltage operation.

A primary object of this invention is to provide a simplified column structure employing a single unitary dielectric cylinder, of glass, alumina, ceramic or other highly insulating material, as the support for the control electrodes of the column.

Another object of this invention is to provide an accelerating column and a method of forming the column that will result in a column of relatively small size to be suitable for operation at high voltage.

Many advantages accrue from the unitary column structure of this invention. These include the lower cost of seal parts and of the glass column, since the conventional multiple cylinder seals require multiple precision molded glass sections, whereas the present invention needs only a single length of molded glass tubing. Moreover, the sealing operations of this invention are less critical and less costly, and many intermediate operations are eliminated when a unitary column is used. The electrode assembling operation is much simpler and easier in the present invention. Cleaning operations and inspections are simpler and less expensive.

A particularly important advantage is the possibility of miniaturization leading to small columns for high voltages, and particularly to high-voltage X-ray tubes of relatively small dimensions.

A major problem in such columns and tubes, as will be explained below in connection with the description of two early modifications in the development of the invention, is to prevent corona. Corona can be fatal to such high-voltage devices.

A further object of this invention is to provide supporting structures, for the control electrodes, that will reduce the tendency for corona to form.

Because of the high energy levels at which tubes and columns operate, enough heat is usually generated to heat the metallic elements and causes stresses due to forces tending toward expansion or distortion. Those stresses ultimately reach the areas of support and set up mechanical reaction forces and stresses. Where a glass column cylinder is used to support the operating electrodes, it becomes especially important that the stresses on the glass walls be kept within safe bounds.

A further object of this invention is therefore to provide novel supports, for the control electrodes, that will have sufficient inherent resiliency to absorb mechanical stresses during operation, so the reaction forces on the glass column wall will be kept at low levels.

This invention, in its departure from the previous conventional type of construction of the accelerator column, employs a single unitary glass tube as the basic support upon which the control electrodes and their feed-in terminals are mechanically supported. As in previous conventional structures, however, the control electrodes are here similarly properly dimensioned and properly co-axially disposed, in spaced axial relationship. In one aspect, however, the unitary glass tube simplifies the operations of mounting the control electrodes, with greater assurance of final proper co-axial alignment.

In another aspect of this invention, the supporting structure for each cylindrical control electrode consists of a set of three individual pin supports sealed and anchored in the glass column and extending radially inward from the wall of the glass column, all in a common plane trans-

verse to the main axis of the column. The three pin supports of each set are equi-angularly spaced around the periphery of the column in such common plane. Alternate sets of pin supports are rotated 60° with respect to adjacent sets. The construction of these supports is such as to provide optimum electrical operating conditions and mechanical support.

Three modifications are illustrated herein, showing progressive development from a simple initial form to a form in which, both in principle and in practice, physical stresses and voltage stress concentration are minimized to the greatest extent.

In the first and second modifications, individual pins of a set are secured to a control electrode and extend through the wall of the glass column and are fuse anchored and sealed in the wall.

In the third modification, each of the three supports of each set embodies a cylindrical Kovar sleeve that extends radially through, and is anchored and sealed in, the wall of the main glass column. A pin is slideable in each such sleeve. Each pin is movable within its Kovar sleeve to a position co-related to the positions of the other pins in the set to assure the proper co-axial disposition and centering of the supported control electrode. Once each control electrode has been correctly disposed in proper co-axial position, the three supporting pins are suitably secured to their Kovar sleeve guides, as by welding, to anchor the pin and to hermetically seal the outer end of the Kovar sleeve.

To locate the Kovar guide sleeves for a set of pins for a control electrode, the selected region on the column for each such sleeve is heated by a glass worker's torch to form a bubble which is then worked to form a hole of suitable size to receive the guide sleeve. The sleeves are then fused to the glass wall with a hermetic seal. The sleeves of each set are angularly equally spaced around the axis of the column. Alternate sets of sleeves are angularly shifted 60° or half of the spacing angle to establish maximum distance between pins of adjacent sets. The column with the sealed-in sleeves is then cleaned. After such cleaning, the several control electrodes are anchored in sequence on the glass column. The complete column assembly is again suitably cleaned and then welded in place between the cathode supporting structure and the anode supporting structure, to provide a hermetically sealed chamber between the cathode and the anode or target plate.

The control column may then be suitably evacuated by a standard procedure. The method of assembling the column and its detailed construction may be more fully realized upon reference to the accompanying specification and drawings in which:

FIG. 1 is a longitudinal sectional view of a first modification of an X-ray tube showing the control column assembly disposed between a supporting plate for the cathode and a supporting flange associated with the target plate or anode of the X-ray tube, and indicates conductors from the cathode and from the anode to an energizing transformer;

FIG. 1-A is a diagrammatic view of the energizing transformer and the tube or column, showing the tap connections to the control electrodes;

FIG. 2 is a perspective view of a control electrode of the first modification of the unitary cylinder assembly, and shows the supporting pins on resilient arms secured to the side wall of the control electrode;

FIG. 3 is an axial view taken on section line 3-3 of FIG. 1, and shows how a control electrode of the first modification is seated axially onto the outer supporting cylinder by seating the pin ends of the supporting arms in pre-formed notches in an edge of a cylinder section that is to be fused to the edge of the next adjoining cylinder section in the column;

FIG. 4 is a plan view of an annular flange to be secured to the body of a control electrode, and to serve as a

support for the electrode, and being in turn supported by the pins at the ends of resilient arms secured to the flange;

FIG. 5 is a longitudinal sectional view of a second modification of a unitary cylinder assembly, in which the control electrodes are supported by separate pins first introduced through holes in the cylinder wall and then anchored in the cylinder wall with a fusion seal;

FIG. 6 is an axial view taken on section line 6-6 of FIG. 5, and shows how a control electrode is positioned in the second modification to receive a set of supporting pins through prepared holes in the supporting cylinder, after which the pins are fused and sealed in the cylinder wall;

FIG. 7 is an axial view, similar to FIG. 6, taken on section line 7-7 of subsequent FIG. 8, and shows how a control electrode is supported in the third modification, by pins inserted through guide sleeves previously fused and sealed in place in the supporting cylinder;

FIG. 8 is a longitudinal view of a third modification of the invention, showing the supports for the electrodes and their angularly shifted positions for alternate electrodes;

FIG. 9 is a perspective view showing two adjacent electrodes of the assembly of FIG. 8, to illustrate further how the support pins of alternate electrodes are angularly shifted to increase voltage creepage distance between the pins of adjacent electrodes; and

FIG. 10 is an exploded view of one form of control electrode and a portion of the outer support cylinder where the electrode will be supported.

As shown in FIG. 1, a first modification of an X-ray tube 20, constructed in accordance with the present invention, comprises a cathode 21 to generate a stream of electrons which are guided and controlled by consecutive control electrodes 22, individually identified as 22-a, 22-b and 22-c, to form a beam, indicated generally by the axis line 23, which impinges upon a target plate 24 supported on the face of an anode 25.

A suitable source of high voltage, external to the X-ray tube 20, and shown here as a transformer 27 whose secondary 28, is electrically connected between the cathode 21 and the anode 25 to establish, in the first instance, a high voltage field to locate the potential gradient in the general direction of the axial path 23 to be taken by the high voltage electron beam moving from the cathode 21 to the target plate 24.

Intermediate connections from the transformer winding 28 are made to the control electrodes 22-a, 22-b and 22-c, to establish the fields to guide and shape the electron beam in its passage between cathode 21 and anode plate 24.

The control electrodes, three of which are shown in this example, are disposed co-axially along the axis 23, and are spaced from each other, as shown in FIG. 1, for insulation and for the purpose of controlling and shaping or focusing the electron stream into a beam according to principles which are well known.

To be properly effective, the control electrodes 22 should be in co-axial alignment with each other and with the common axis 23. A three-point support is provided for each control electrode 22 to provide a relatively stable supporting system to maintain the co-axial disposition of the electrodes.

The ultimate support for the control electrodes 22 is derived from a unitary di-electric column, as a tube or cylinder 35, of glass or ceramic. The cylindrical column 35 supports the control electrodes 22, and also confines and encloses them in an evacuated chamber or region 37 within the cylinder 35. This chamber 37 is hermetically sealed, to maintain either a high vacuum or a predetermined selected pressure for the proper operation of the particular tube to which this invention is applied. For convenience, the tube 35 is hereinafter designated as

glass, it being understood that the tube may be made of ceramic or other suitable di-electric material.

The glass column 35 is supported at its opposite ends on the supporting structures associated with the cathode 21 and with the anode 25, respectively. The connections between the column and those supporting structures are made as hermetic seals, in order to maintain the desired vacuum or pressure condition within the unitary glass column 35. The details of those supporting and sealing connections are considered below.

The construction of the supporting column, and the included control electrodes 22 will be described first.

FIGS. 2 and 3 show a first modification of a control electrode 22 having three resilient pin brackets 41 anchored on the electrode body 40 at regions equally spaced around the periphery of the body 40. The brackets 41 are supported as cantilevers, with the free end of each bracket supporting a sealing pin 42 to be sealed in the wall of a glass cylinder section 44 of column 35.

In that first modification, the final column 35 is made up of separate glass cylinder sections fused together. The edges of one section 44, as shown in FIG. 3, are provided with notches or grooves 45 in which the supporting and sealing pins 42 are seated for proper positioning. After the electrode body 40 is properly positioned the pins 42 are fused and sealed in position on the section 44. The outer end of each pin 42 is shown provided with a thin layer of wetting glass 46 on the pin 42 to provide glass filler for the notch 45 in the fusing and sealing operation.

The pins are used first to position the control electrode in proper co-axial position, and then the pins are anchored and sealed in position by fusing the wetting glass 46 on each pin to the glass column.

FIG. 4 shows a variation in which an annular supporting flange 50 that is to support a control electrode serves as an anchoring plate for one end of each of a set of three resilient cantilever-mounted pin brackets 51. The outer or free ends of brackets 51 serve as anchoring pins 52 and are provided with a layer 53 of wetting glass for sealing to a glass column, similar to the method shown in FIG. 3. Where a ceramic column is used, the wetting layer 53 would be a layer of the same material as the ceramic column, bonded to the pin.

FIGS. 5 and 6 show a second modification embodying the broad principles of the present invention. The general arrangement of the cathode, anode and control electrodes with the supporting glass column is similar to the arrangement in FIG. 1. The major problem of supporting the individual control electrodes is solved differently.

As shown in FIG. 5, the cathode 60 is supported on and sealed to one end of the glass column 61. The anode 62 is sealed to the other end of the supporting column, and the control electrodes 63 are supported on the column 61 at locations between the cathode and the anode.

In this second modification, FIGS. 5 and 6, each control electrode 63 is provided with a set of three pin-receiving sleeve brackets 65. These brackets 65 are welded to the body of control electrode 63 in co-planar radial positions equally spaced around the periphery of the electrode body.

The glass column 61 is prepared, as shown in FIG. 6, by providing a set of three holes 66 to receive the pins 67-a, 67-b and 67-c that are to support and position the control electrode 63. As indicated, the holes 66 are co-planar and angularly equally spaced and radially formed in the wall of the glass column 61.

The three positions of the three pins 67, shown in FIG. 6, clockwise from the bottom pin 67-a, illustrate the steps in assembly of the pins 67 in the sleeve brackets 65, from outside the glass column, while the control electrode 63 is held in position by a suitable supporting tool, such as a mandrel (not shown) extending into the glass column. The pins are inserted into the holes in the sleeve brackets for a tight friction fit. Alternatively, the pins may be soldered or welded to the brackets. In either case, the pins are then utilized to position the control electrode 63

in proper co-axial position, after which the pins are fuse sealed in position in the glass column 61, with the glass adjacent and fused to the pins shaped to form a concave curved junction or fillet 68 to relieve stresses.

Since such columns, and X-ray tubes utilizing them, are intended to operate with electric fields of millions of volts, the stresses induced by the electric fields must be considered.

The stresses induced by an electric field are of two types. First there is a mechanical stress on a metal element which serves as a terminal for a voltage or potential point. That stress is relatively negligible. Second, and especially important in this case, however, is the electrical stress that is a function of potential gradient. Here, potential gradient is determined by the field strength and by the sharpness of the surface of the metal element, in this case the curvature of the body of the pin sealed in the wall of the cylinder.

As the pin becomes smaller in diameter, the peripheral curvature of arc becomes sharper, and the potential gradient becomes steeper, thereby enabling corona to form more easily. Corona in such a tube can quickly lead to destruction of the tube. But, if the pin is increased in diameter to reduce corona possibilities in an X-ray tube with higher voltages, the pin may be too stiff to provide the slight resiliency that may be essential and that is desired.

Thus, the pin type supports in FIGS. 3 and 6, when thick enough for necessary strength, could not always be relied upon to be sufficiently resilient to take up some of the stresses and to isolate them away from the glass column. Moreover, the small curvature of the pin in the second modification is sharp enough to promote corona at the higher voltages.

In the third modification of this invention, as shown in FIG. 7, and in the subsequent figures, a different type of pin-anchoring support is employed, to provide the necessary strength to support the control electrode, and, yet, at the same time, to provide a substantial degree of resiliency to yield under the forces of the various stresses occurring during operation, including mechanical, thermal and electric stresses, and still further, at the same time, to establish a corona-discouraging surface characteristic for higher voltage operation.

As shown in FIGS. 7-10 inclusive, each control electrode 70 is provided with a set of three brackets 72, equally spaced around the periphery of the control electrode, and each bracket is shown having a base secured to the body of the control electrode 70. Each bracket 72 has a perpendicular lug or flange 74 projecting radially outward from the base part secured to the electrode 70. The three brackets serve to support an annular ring 73 which fits over the base portions of the brackets 72 with a loose fit, and rests against the perpendicular radial lug flanges 74 of the brackets. The annular ring 73 is provided with three equally spaced holes 76 for alignment with corresponding bolt holes 77 in the perpendicular flanges of the brackets 72. The annular ring 73 may then be tightly secured to the three angle brackets 72 by suitable bolts and locking nuts, or by brazing, welding, etc., whereupon the annular ring 73 and the three brackets 72 constitute a relatively rigid and integral supporting element for the cylindrical electrode 70. Alternatively, the annular ring 73 may be welded directly to the electrode body 70.

The annular ring 73 now also serves as a rigid connecting element to be mechanically connected to the unitary glass column 75.

To support each annular ring 73 and its control electrode 70 from the glass column 75, a set of three tubes 80 of Kovar metal are employed. These tubes are of thin walls, from 0.005 to 0.015 inch thick. Each sleeve 80 is fuse sealed in the glass column 75. To accomplish that, three appropriately located areas of the glass column, relatively co-planar in a plane transverse to the axis of the column, are heated and softened, and holes formed to

receive each of the Kovar sleeves 80. Each Kovar tube 80 is then fused to and anchored in the glass column to provide a hermetic seal. The glass seal is preferably shaped to form a fillet 81 to aid in reducing mechanical stresses between the glass cylinder and the metal tube. The Kovar tubes 80 of each set are thus disposed radially in co-planar relation, and are equally spaced around the periphery of the glass column 75.

A control electrode 70 may now be mechanically coupled to its related supporting set of three Kovar sleeves 80. As shown in FIGS. 7 and 10, a pin 82 is provided to slide-fit into each Kovar sleeve 80, and to slide easily through the Kovar sleeve 80 to project into one of three spaced holes 83 in the edge of the annular ring 73. Each hole 83 is of appropriate dimension and location to receive the front end of the Kovar pin 82. As shown in FIGS. 7 and 10, the front or inner end of each pin 82 is sharply tapered to a point 82-a. That sharp point will enable the pin 82 to easily find its intended hole 83 in the annular ring 73, but it has a more important function in helping to support the associated control electrode, explained further, below.

After the three pins 82 of a set are inserted into their annular ring 73, and suitably adjusted to position their associated control electrode co-axially, the outer ends of the pins are welded to their Kovar tubes to form hermetic seals.

The pins are also preferably of Kovar to simplify the welding of the pin to the sleeve. The pin could, of course, be made of stainless steel or other metal which could be welded to Kovar. Similarly, in the first and second modifications the pins would be of a metal or alloy to which glass would readily fuse, and which would otherwise serve the purposes for which intended.

The sharply tapered point 82-a on each pin 82 serves another important purpose. It provides a substantially true point contact between the Kovar sleeve structure and the control electrode structure, for the transmission of physical stresses, however arising. The stresses may be permitted to establish slight adjustments in form of the pin about such contact point as a center, without superimposing the full stresses on the glass seal. Thus, the point 82-a may flatten and absorb stress to prevent damage to the glass-Kovar seal.

The stresses thus divide themselves between the tapered point of the pin and the outer end of the pin where it is welded to the Kovar sleeve, as well as in the body of the pin to the extent of the inherent resiliency of the pin. The pointed pin and its resilient supporting guide sleeve thus serve as a stress absorber and to take up any physical stresses which the control electrodes would otherwise impose on the glass tube which serves as the ultimate support for the electrode.

In order to provide additional resiliency for absorbing physical stress and to prevent the stresses from affecting the seal in the glass column, the guide sleeve 80 is chosen of appropriate dimension to provide a desired degree of resiliency.

As a further feature, the guide sleeve 80 is chosen of such external diameter as to present an arcuate surface having insufficient sharpness to induce corona at the potential gradient established at the sleeve for the voltage utilized in the operation of the X-ray tube in this case.

Before glass column 75 is fitted with the control electrodes, the two ends of the column are fitted with separate end rings 85 and 86, also hermetically sealed into the end edges of the glass column. These two end rings are then fitted and hermetically sealed to their supports, respectively associated with the cathode and the anode. As shown in FIG. 8, the end ring 85 is provided with a flange 85-a which is seated against an annular washer 88 integrally secured to a supporting plate 90 for the cathode structure assembly. The flange 85-a is joined to the washer 88 with a hermetic seal.

The other end ring 86 is also arranged to be hermetically sealed to its supporting plate 95, that is welded or brazed on the final control electrode 96 that is electrically connected to the anode 110.

The voltage that may be applied to the accelerator column, in this case the X-ray tube, may be as high as one or two million volts peak voltage, or higher, between the cathode and the anode. Usually, this voltage is supplied from the secondary winding of a step-up transformer that constitutes a resonant system with the components of the accelerator column, as illustrated in FIG. 1-A. This column would work equally well with other high voltage sources, such as Van de Graaf generators, Marx generators, etc.

The control electrodes receive their voltages from progressive intermediate taps on the transformer, or from other suitable voltage dividing devices. With such high voltages on the electrodes and their supporting elements it becomes important to shape all surfaces to limit the voltage concentration stresses of any potential gradient to a value that will be below any voltage values that would initiate corona.

The annular ring 73 surrounding and supporting each control electrode 70 serves to provide a substantial area sufficient to keep the average voltage level below a dangerous value. This feature of substantial area provides an important benefit in co-operation with the Kovar sleeves that support the pins, as will be explained below.

An important feature is that the Kovar sleeves which carry the supporting pins for the annular ring are of sufficient diameter to provide a peripheral curvature that prevents an excessive potential gradient from forming in response to the electric field. The potential gradient tends to increase at corners and sharp edges of metal parts that serve as voltage terminals or electrodes. When the potential gradient reaches certain values, depending upon the nature and pressure of the ambient atmosphere, corona will form. In order to prevent corona, the potential gradient at any point in the X-ray tube must be kept below the corresponding dangerous value. That is done here, in the first instance, by rounding all edges and increasing any curved surface to a curvature whose radius exceeds a selected minimum value.

Further, in this case the Kovar sleeves 80 are made larger in diameter than necessary for strength alone. By using a sleeve, the greater strength obtained from a tubular structure permits thinner metal to be used in the sleeve. The thin sleeve is extended somewhat beyond the outer surface of the glass column to provide an outboard or cantilever support for the outer end of pin 82.

This cantilever beam section of the sleeve provides some inherent energy-absorbing resiliency which becomes very important in this application. Mechanical stresses that result from heating of the electrodes and consequent distortion or displacement are transmitted through the pins 82 and absorbed in the sleeves.

As previously indicated, the pin provides a stress-absorbing feature at its front end sharpened to a point 82-a. As now further explained, the back end of the pin in association with the cantilever sleeve 80 provides additional resiliency to absorb mechanical stresses before they reach the wall of the supporting cylinder 75. The glass seals through which the Kovar sleeves are supported are also shaped to embody a curved or fillet form, also to limit potential and physical stress concentrations.

By reason of the use of the sleeve 80 with a larger external diameter, the potential gradient on any point of the sleeve surface is below the value required to initiate corona. By this expedient, the glass tube can be used to operate with higher voltages.

Such increase in the radius of curvature on the pin sleeve 80 is effective to suppress the tendency to form corona both on the inside of the glass column and on the outside.

A further feature of importance in controlling the elec-

tric fields to prevent field concentration and resultant corona, is the annular ring 73. That ring 73 serves both a mechanical and an electrical function. Mechanically it serves as a connection between the pins 82 and the control electrode 70. Electrically it serves to provide an enlarged equi-potential surface with the three co-planar pins 82 and sleeves 80. It has actually been found that enlarging the diameter of the annular ring to bring the ring closer to the inner surface of the glass column has minimized propagation of sliding discharges from one section to an adjacent section.

In the operation of the column, one pin-sleeve may be used as a terminal for the associated electrode, to which a voltage connection may be made from the external tapped transformer or voltage-divider. The increased area of the annular ring reduces even further any field concentration on the terminal pin. It will be seen, upon reference to FIG. 7, that the periphery of flange ring 73 is quite close to the inner end of pin sleeve 80. The space or gap 83 is too short to admit enough field flux to reach corona-inducing quantities. The field flux is mainly distributed on the exposed surfaces of the pin sleeve 80 and the flange ring 83. Since those surfaces constitute an equi-potential surface, the electric field becomes sufficiently divided and distributed to be kept below corona-forming levels.

While Kovar metal has been referred to throughout the specification, it is to be understood that other metals could be used in place of Kovar, provided suitable glass is chosen. For example, lime glass and 430TV stainless steel, or sealmet, or Nickerlex, etc. Similarly, where a ceramic tube would be used for the supporting column, compatible metal guide sleeves should be employed.

The detail construction of the cathode 100, and of the anode 110 may follow conventional practices. As shown in FIG. 8, the cathode-supporting plate 90 serves also as a terminal to receive a suitable plug connector 101 from the exciting transformer or equivalent voltage source. Also shown is a glass stem connection 102 for connection to an external exhaust system to evacuate the column, and then to be sealed off to hold the vacuum.

At the other end of the tube, the anode 110 is supported at the outer end of the final control electrode 96. The anode 110 carries a conventional target plate 111 disposed at an angle to direct X-rays out of a window 115. The window 115 consists of a suitable metal, transparent to X-rays, and of a frame 116 which is hermetically sealed to the outer extension of the final control electrode 96, to preserve the vacuum in the column.

This invention thus provides a simple sturdy construction for an accelerator column which may be easily constructed and assembled and cleaned, and in which the various components and elements are suitably shaped to guard against concentrated field stresses. Various modifications may be made in the detailed construction of the various elements within the scope of the invention as defined and to be defined in the claims.

What is claimed is:

1. A high voltage tube of the electro-beam type having a cathode to generate a beam, an anode to receive the beam, and a beam-control structure between the cathode and the anode to control the beam in an intended path between the cathode and the anode, said control structure comprising:

- (a) a unitary glass cylinder;
- (b) means supporting said glass cylinder between the cathode and the anode in position substantially co-axial with said intended beam path;
- (c) a plurality of beam-focusing cylindrical electrodes within the cylinder to define the beam path; and
- (d) means sealed through the wall of the glass cylinder and characterized by a degree of resiliency for supporting each of said cylindrical electrodes substantially co-axially within the glass cylinder.

2. A high-voltage tube, as in claim 1, in which the supporting means sealed through the wall of the glass cylinder comprise several sets of supporting pin structures for the several cylindrical electrodes, the pin structures of each set for each electrode extending through and being fused and anchored in the wall of the glass cylinder in co-planar relation.

3. A high-voltage tube, as in claim 2, in which each focusing and accelerating electrode is provided with supporting means to which the inner ends of the associated supporting pin structures are mechanically coupled to provide a stable three-point support for the supporting means and the cylindrical electrode.

4. A beam-type tube comprising:
- (a) a beam-generating cathode;
 - (b) a beam-target anode spaced therefrom;
 - (c) a rigid unitary elongated di-electric structure consisting of a single cylinder for supporting and enclosing the cathode and the anode; and
 - (d) a beam-controlling assembly including
 - (1) a plurality of beam-focusing cylindrical electrodes, and
 - (2) resilient stress-absorbing supporting elements fused and sealed through the wall of the di-electric cylinder and supporting the beam-focusing electrodes in spaced and co-axial alignment between said cathode and said anode.

5. A high-voltage tube of the electron-beam type, comprising:

- (a) a cathode to generate an electron beam;
- (b) a supporting structure for the cathode;
- (c) an anode target to receive said beam;
- (d) a supporting structure for the anode; and
- (e) means to control said beam and to guide said beam along a predetermined axial path between the cathode and the anode, said control and guide means comprising a plurality of electrically conductive cylindrical electrodes;
- (f) a unitary single elongated di-electric cylinder encircling said axial path, the cylinder being closed at one end by said cathode and its supporting structure, and being closed at the opposite end by the anode and its supporting structure; and
- (g) resilient means anchored on and supported from said di-electric cylinder and serving to support the cylindrical electrodes in co-axial alignment along said axis, said resilient means consisting of a tube of thin refractory metal fused in and extending outward of the di-electric cylinder to constitute a cantilever with some slight resiliency, and of a rod co-axially disposed in the tube, the outer end of the rod being welded to the outer end of the tube to seal that end closed, and the inner end of the rod extending inwardly beyond the inner end of the tube and into the elongated di-electric cylinder to mechanically couple to the associated cylindrical electrode to provide a point of support for said electrode.

6. A high-voltage tube, as in claim 5, in which each rod is hermetically sealed in said cantilever tube to maintain the hermetic seal at that region of the di-electric cylinder, said sealed cantilever tube having an external diameter with a curvature to establish an equi-potential contact line of sufficient length at the exposed edge of the di-electric seal to reduce the maximum electric field intensity at any point on such contact line to a level substantially below corona-forming gradient at the pressure conditions within said di-electric cylinder, said rod having an external diameter with a curvature to establish an equi-potential contact line that is sufficiently short to result in an electric field intensity at some point on such contact line to a level substantially above corona-forming gradient at the pressure conditions within said di-electric cylinder

if said rod were sealed in said di-electric cylinder without the intermediary of said cantilever tube coaxially disposed about said rod.

7. A high-voltage beam type tube, comprising:
- (a) a unitary di-electric cylinder;
 - (b) a cathode at one end of the cylinder to generate an electron beam to traverse the cylinder, and an anode at the other end of the cylinder to receive the beam;
 - (c) a plurality of electrically conductive cylindrical control electrodes in the cylinder to control and guide the beam; and
 - (d) means supported from the di-electric cylinder for supporting the control electrodes in predetermined relative positions co-axially within the cylinder, said supporting means being characterized by an inherent resiliency to enable said means to absorb mechanical stresses generated in the control electrodes by heat and electric fields in the tube during operation, and, thereby, to prevent such stresses from affecting the di-electric cylinder.
8. A beam-type tube comprising:
- (a) a beam-generating cathode;
 - (b) a beam-target anode to receive the beam;
 - (c) means for controlling and guiding the beam in passage between cathode and anode;
 - (d) a rigid unitary di-electric structure for supporting the cathode and the anode in fixed spaced relation; and
 - (e) resilient tubular sleeve means anchored on the di-electric structure for supporting the control and guiding means for the beam intermediate the cathode and the anode, and said sleeve means serving to provide a resilient connection to said control and guiding means to prevent transmission of excessive mechanical stresses to the di-electric structure from the controlling and guiding means as generated in said controlling means by thermal and electric conditions within the tube during operation.
9. A beam-type tube comprising:
- (a) a unitary rigid elongated glass envelope;
 - (b) a beam generating cathode structure supported at one end of said envelope;
 - (c) a beam-target anode structure to receive the beam and supported at the other end of said envelope;
 - (d) beam-control electrodes disposed along the beam path axis between cathode and anode; and
 - (e) a three-point support assembly anchored on the envelope and connected to support each control electrode, said assembly including a thin metallic sleeve fused and sealed in the wall of the envelope and extending outwardly from said wall, and hermetically sealed at its outer end, said sleeve having some inherent limited resiliency by reason of its thin wall, its diameter, and its length and its support as a cantilever from said envelope; and said assembly further including an elongated rod supported at one end from the outer end of the cantilevered sleeve and the other end of the rod supporting the control electrode.

10. A beam-type tube, as in claim 9, in which each three-point support assembly comprises three individual sleeve anchor elements sealed into the wall of the glass envelope and characterized by a degree of resiliency so mechanical stresses that become established in the associated control electrode by thermal and electric conditions in the tube during operation will be absorbed in stressing the anchored sleeve element and not be transmitted to the glass cylinder.

11. A high voltage beam type tube to be energized

from an external source of high voltage, the tube comprising:

- (a) a cathode and a support therefor;
- (b) an anode and a support therefor;
- (c) a di-electric cylinder sealed to the two supports to define a hermetically sealed elongated chamber with the cathode and the anode at opposite ends;
- (d) a plurality of beam shaping and guiding electrodes co-axially arranged within the cylinder and between the cathode and the anode; and
- (e) means supporting said electrodes from the di-electric cylinder, said supporting means including elements hermetically sealed through the wall of the cylinder to provide terminals for connection to the external energizing source, said elements being characterized by external dimensional surface contours that keep the potential gradients below corona-inducing values, said supporting means also including a rod physically coupled to each of said elements for connecting each of said elements physically to one of said beam shaping and guiding electrodes, said rod being characterized by external dimensional surface contours that would keep the potential gradients above corona-inducing values in the absence of said elements hermetically sealed through said wall of said cylinder.

12. A high-voltage beam type tube, comprising:

- (a) a unitary di-electric cylinder;
- (b) a cathode at one end of the cylinder to generate an electron beam to traverse the cylinder, and an anode at the other end of the cylinder to receive the beam;
- (c) a plurality of electrically conductive cylindrical control electrodes in the cylinder to control and guide the beam;

- (d) means supported from the di-electric cylinder for supporting the control electrodes in predetermined relative positions co-axially within the cylinder, said supporting means being characterized by an inherent resiliency to enable said means to absorb mechanical stresses generated in the control electrodes by heat and electric fields in the tube during operation, and, thereby, to prevent such stresses from affecting the di-electric cylinder;
- (e) an annular flange ring secured to each said cylindrical control electrode; and
- (f) said supporting means for each said control electrode including three tubular sleeves sealed into said di-electric cylinder, and in each said sleeve a pin being slideable during manufacturing assembly through its tubular sleeve into the flange ring on the control electrode to aid in locating said electrode and to co-operate with the other pins as a set to provide a three-point support for said control electrode, each pin being then hermetically sealed to its tubular sleeve during assembly of the tube.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,034,009

May 8, 1962

Michael J. Zunick et al.

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

Column 10, line 59, for "electro-beam" read -- electron-beam --; column 12, line 30, for "unitray" read -- unitary --.

Signed and sealed this 9th day of October 1962.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

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