April 13, 1965 M. R. CLELAND 3,178,601

BEAM TUBE

Filed July 18, 1961

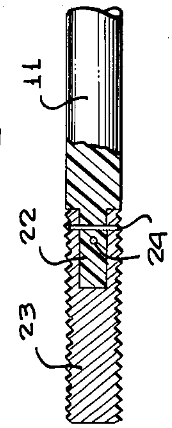

FIG. 3

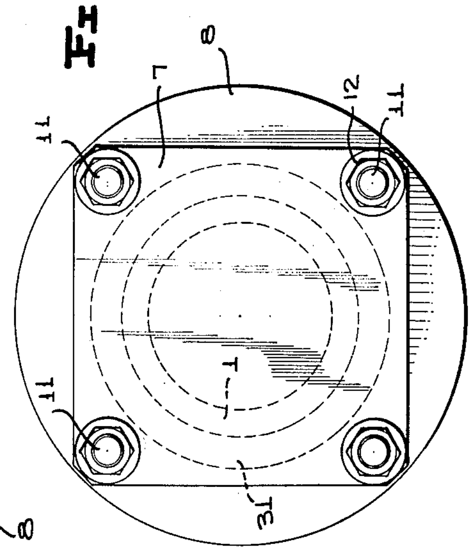

FIG. 2

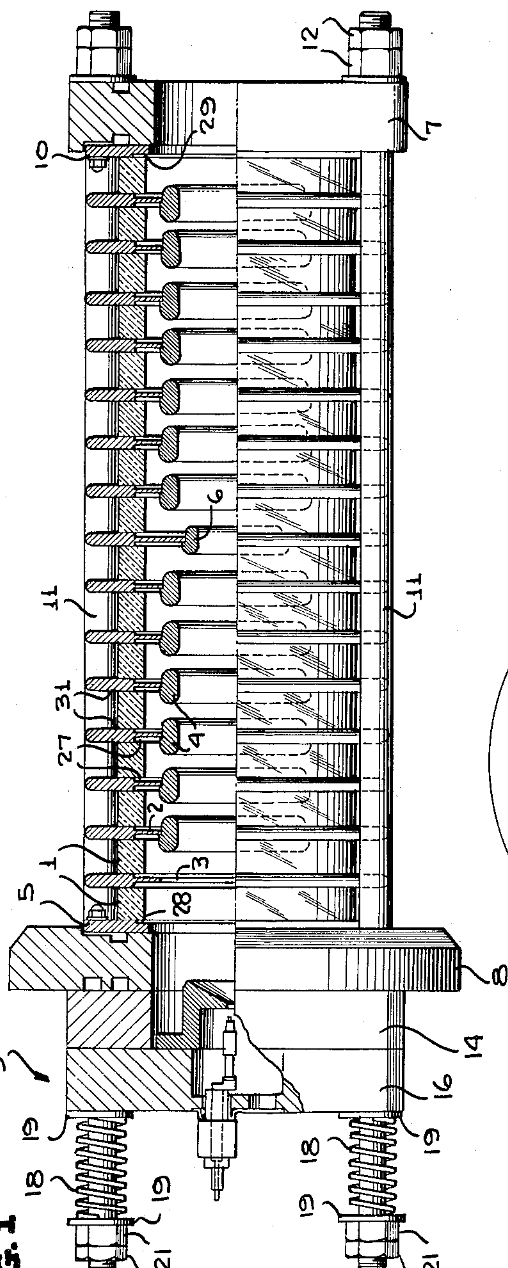

FIG. 1

INVENTOR

Marshall R. Cleland

BY Hurvitz & Rose

ATTORNEYS

United States Patent Office

3,178,601

Patented Apr. 13, 1965

1

3,178,601

BEAM TUBE

Marshall R. Cleland, Huntington Station, N.Y., assignor to Radiation Dynamics, Inc., Westbury, N.Y., a corporation of New York

Filed July 18, 1961, Ser. No. 124,928
5 Claims. (Cl. 313—63)

The present invention relates to high-vacuum, high-voltage, electron and ion beam acceleration tubes and more particularly to methods of fabricating such tubes and to structures which result from such method, which minimize spontaneous discharge currents and sparking within the tube, and which permit the generation of large current ion and electron beams with substantially no radial scattering of the beams.

The high-vacuum, high-voltage acceleration tubes of the type with which the present invention is concerned, have alternately arranged and axially aligned metallic discs and hollow glass cylinders bonded one to the other. The metallic discs extend both internally and externally of the glass cylinders and are centrally apertured so as to provide a path for an electron or ion beam. A hot cathode or ion source structure is arranged at one end of the column formed by the alternate sections of hollow cylinders and apertured metallic discs while a target structure or electron permeable window is provided at the other end of the column. The metallic discs are electrically connected to a voltage divider generally such that an accelerating field is established along the column in a direction away from the source structure. It is conventional in such tubes to provide conductive collars disposed in the apertures of and connected to each of the conductive discs so as to shield the electron or ion beam from non-uniform electrostatic charges which may accumulate on the inner glass surfaces of the glass cylinders.

In the fabrication of such tubes, it is conventional to bond the edges of the glass cylinders and the mating surfaces of the metal discs, one to the other, by means of a synthetic resin to provide a vacuum-tight seal so that a high vacuum may be maintained within the column. It is essential that none of this resin be located internally of the tube where it may be bombarded by stray particles, such as electrons and ions. Bombardment of the glue or resin by electrons and/or ions causes this latter material to become decomposed, liberating gas in the vacuum chamber and leaving a carbonaceous residue which may become deposited in specks over the interior surfaces of the tube and materially detracts from the operation thereof. Specifically, the resin which forms on the interior of the glass causes currents to flow across the glass between the metallic discs and etches these surfaces. Further, the presence of this material produces internal sparking and seriously hinders operation of the apparatus. In the prior art method of fabricating such tubes, the resin material, most commonly employed is a vinyl acetate which provides a self-supporting electron tube structure. The acetate has to be painted in rings or annuli on the mating surfaces of the glass cylinders and the metallic discs and extreme care has to be taken to insure that none of the resin is disposed interiorly of the tube for the reasons set forth above. After the resin is applied, the metal discs and cylinders are assembled and then placed in an oven to cure the resin to provide the permanent seal required. Great care has to be exercised during the heat curing stage to prevent the formation of bubbles and gas pockets in the cured resin which seriously hinder the ability to maintain a vacuum in the tube. In order to apply the resin to the elements of the tube, it must be incorporated in a volatile solvent which is driven off during the curing process and which tends to leave voids and gas pockets in the cured material. A further disadvantage

2

of this method of fabrication is that the curing process takes several days to complete. This difficulty coupled with the care with which the resin has to be applied to the metal and glass elements and the care required to prevent the formation of voids in the cured resin causes the entire assembly process to be extremely tedious and quite time consuming, often unsuccessful, and requires highly skilled personnel.

In accordance with the present invention, the problems experienced with the use of vinyl acetate have been overcome by employing an epoxy resin which does not require solvents and which sets at room temperatures. Further, the epoxy resin must have flow properties such that the material can flow by capillary action between the assembled metallic and glass elements; that is, the resin must be free flowing at room temperature. More specifically, the metal discs and glass plates are assembled, in interleaved relationship, into a column and held together by cinch rods appropriately located externally of the interior of the column. The mating surfaces of the metal plates and glass are ground and dimensioned so as to provide a sufficiently tight contact to support capillary action. The epoxy resin is now painted about the circular exterior of each of the metal to glass interfaces and flows into this surface by capillary action. The metal plates are undercut adjacent but outwardly of the inner surfaces of the glass cylinders so as to terminate the capillary action in a region remote from the interior of the tube column. Thus, it is assured that none of the resin is carried into a region where it is subject to ion or electron bombardment. The epoxy resin employed as indicated above cures at room temperature and since it is a free flowing resin and does not require a solvent, no difficulty is experienced with formation of cells and gas pockets. Also, a furnace is not required since the resin cures at room temperature. The entire assembly operation requires only a few hours time of a relatively unskilled individual as opposed to the extended period required to assemble a tube of the prior art type. The epoxy resins employed may be Type EC–1294 of the Minnesota Mining and Manufacturing Company. A curing agent, No. 1468, of the same company is also employed and is incorporated in the resin prior to application to the tube. In addition, resins of the type Eastman 910, Locktight or Anaerobic Permafil may be employed. See also U.S. Patents Nos. 2,975,155 and 2,977,332 for chemical formulas of epoxy resins which are suitable for utilization in the present method. These resins all cure at room temperatures and do not require solvents and therefore the bubbling and heat treating problems are eliminated.

The specific resins employed are relatively brittle when cured and cannot support the column independently of other support means. Therefore, the cinch rods which are employed during assembly are permanently retained as a part of the final structure. It is important that the cinch rods maintain their shape during the life of the tube; that is, that the rods cannot stretch and, in consequence, fiber glass reinforced polyester rods are employed. Compression springs are employed at the ends of the rods so as to maintain a constant tension throughout the life of the rods.

The epoxy resins are sufficiently brittle that they cannot stand constant flexure which would result if elements of different coefficients of thermal expansion are employed. In consequence, the glass or metallic elements are chosen so as to have substantially the same coefficients of thermal expansion. For instance, a soda-lime glass, Corning 0080 or Kimball R–5, may be employed with stainless steel or titanium discs. All of these materials have substantially the same coefficient of thermal expansion. Other combinations of glass and metal elements of the proper coefficients of expansion and an epoxy resin of the type mentioned above, a tube having qualities superior to the tubes of the prior art may be rapidly and properly assembled by relatively unskilled personnel. The assembly process involves only a few simple steps and no problems of heating, bubbling of the resins or location of the resins are encountered.

It has been mentioned above that it is conventional to employ hollow metal cylinders interiorly of the tube and located in the apertures in the metal discs in order to shield the discharge region from electrostatic charges which may momentarily build up on the interior surface of the glass elements; even though these latter elements have a low electrical resistivity and tend to maintain these surfaces discharged. In accordance with another aspect of the present invention, one or at the most three of these cylinders have a smaller diameter than the remaining cylinders in order to greatly reduce the spontaneous discharge or dark current within the tube when they are first started up after the interior of the tube has been exposed to air. This may occur the first time the tube is employed or at any time after the tube is opened for such purposes as replacing a cathode filament or electron window. It is a known fact that when a high-voltage, high-vacuum acceleration tube has high voltage applied thereto, it is necessary to increase the voltage slowly so as to out-gas the interior surfaces of the tube of contaminating materials. Specifically, as the voltage of the tube is raised, the contaminants begin to ionize, and stray electrons bombard these materials and cause them to ionize. Oppositely charged particles, including electrons and ions, travel in opposite directions and ionize further materials and produce secondary emissions from the metallic discs encountered along their path of travel. If the voltage is raised too fast, a relatively large current results which leads to spark breakdown within the tube preventing full voltage from being developed, damages the interior surfaces of the glass and metal elements and also may expose the target material to unwanted radiation flux which is unfocused and of variable energy so that it is impossible to determine the dose which the target material has received. When the voltage is brought up rapidly, the spontaneous currents may amount to as much as 30 microamperes. It is therefore necessary in such tubes to increase the voltage slowly so that these currents are maintained at a small value.

Several suggestions have appeared in the prior art for overcoming or at least reducing spontaneous discharge currents and one suggestion has been to provide a gradual taper of the axial apertures in the metal plates. These tapers may take various shapes such as linearly increasing in size as one proceeds away from the cathode or decreasing in size from both ends toward the center, etc. These various arrangements do tend to decrease the current somewhat, but the improvements do not warrant the expense of fabrication. In accordance with the present invention, it has been found that, if the inside diameter of one of these metallic discs or of one of the metallic cylinders disposed in the aperture in and connected to the metallic disc adapted to be connected to approximately the half voltage point of the divider, is somewhat smaller than the remainder of the apertures or cylinders, which are all substantially of the same internal diameter, the spontaneous discharge current can be reduced from 30 microamperes at 1.5 million volts, without energization of the filament, to less than one microampere. In consequence, the high voltage may be applied to the tube much more rapidly than in the prior art structures and, in fact, can be applied sufficiently rapidly to reduce the energizing time from several hours to a few minutes. It has been found that, for example, if a tube has metallic cylinders or discs having inside diameters of two inches and the centrally located cylinder has an inside diameter of one and one-half inches the results indicated above are obtained. It has also been found that a further improvement, although not as striking as the results obtained as indicated above, is obtained if identical cylinders or discs of smaller diameter are also located at approximately the one-quarter and three-quarter voltage points. However, for most purposes the use of one cylinder of smaller internal diameter in the center of the tube is sufficient to reduce the spontaneous discharge current to a very small value and to permit the tube to be brought up to operating voltage relatively rapidly. The advantage of this structure over the previously cited prior art structure is that all of the metallic discs, except one, are identical and this results in a saving in cost of manufacture.

It is an object of the present invention to provide a method of manufacture of high-vacuum, high-voltage electron and ion beam acceleration tubes which is simple and rapid, which does not require highly trained technical personnel to assemble the tube and which does not require specialized equipments such as tall ovens having exceptional temperature control and temperature uniformity.

Another object of the present invention is to provide a method of fabricating high-vacuum, high-voltage electron and ion beam acceleration tubes which employs a liquid epoxy resin curable at room temperature and which does not require solvents and therefore, does not require extreme care during curing to prevent bubbling of the solvent as it evaporates.

It is still another object of the present invention to provide a method of fabricating high-voltage, high-vacuum electron and ion beam acceleration tubes employing appropriately finished and dimensioned alternate hollow glass and apertured metallic elements in which method an epoxy resin may be painted on the exterior of the tube so as to flow by capillary action into the entire region between the glass and metallic elements.

It is another object of the present invention to provide a method of fabricating high-vacuum, high-voltage electron and ion beam acceleration tubes employing alternately arranged apertured metallic discs and hollow glass cylinders in which an epoxy resin is painted on the exterior of the tube so that it flows by capillary action into the region between the glass and metal elements and in which the top and bottom surfaces of the metallic elements are stepped so as to terminate the capillary flow in a region external to the interior of the glass wall.

It is yet another object of the present invention to provide a method of fabricating high-vacuum, high-voltage electron and ion beam accelerators employing alternately arranged hollow glass cylinders and apertured metal discs and further employing a room temperature setting epoxy resin which is painted on the exterior of the assembled glass and metal elements and which flows by capillary action and without the need for a solvent into the region between the glass and metal elements.

It is another object of the present invention to provide a high-vacuum, high-voltage electron and ion beam acceleration tube employing alternate sections of hollow glass cylinders and apertured metallic discs, the mating surfaces of the glass and metal elements being ground to a finish to support capillary action of an epoxy resin and the discs being undercut so as to terminate the capillary action in a region outwardly of the interior of the glass.

It is another object of the present invention to provide a high-vacuum, high-voltage electron and ion beam acceleration tube having alternately arranged hollow glass cylinders and apertured metal discs and further employing hollow metallic cylinders arranged axially of the tube in the apertures of the metal disc and further employing a single hollow metallic cylinder of lesser diameter than the remaining cylinders; the cylinder of lesser diameter being connected to the metallic disc adapted to be connected to the approximate half voltage point of the system.

It is still another object of the present invention to provide a high-vacuum, high-voltage electron and ion beam accelerator employing alternately arranged hollow glass cylinders and apertured metal discs having approximately the same temperature coefficients of expansion; the interface between the discs and cylinders being sealed by means of a room temperature curing free-flowing epoxy resin and further including a plurality of metallic cylinders arranged axially of the tube in the apertures in the metal discs with no more than three of these cylinders being of lesser diameter than the remainder of the hollow metallic cylinders; these three cylinders being connected to approximately the one-quarter, one-half and three-quarter voltage points on a voltage divider employed with the tube when it is operational.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of one specific embodiment thereof, especially when taken in conjunction with the accompanying drawings, wherein:

FIGURE 1 is a vertical section in elevation of a beam tube of the present invention;

FIGURE 2 is an end view illustrating the relative shapes and sizes of the opposite end plates employed in the beam tube of the present invention;

FIGURE 3 is a cross sectional view of the cinch rods employed in the apparatus of the invention.

Referring now specifically to FIGURES 1 and 2 of the accompanying drawings, the beam tube comprises a plurality of hollow glass cylinders **1** alternately arranged and axially aligned with metallic discs **2** having centrally located apertures **3**. The number and size of the hollow glass cylinders **1** and discs **2** is a function of the beam current and the voltage of the apparatus. In a specific arrangement, for instance, a one and a half million volt machine, employs sixty-four hollow glass cylinders of soda lime glass having an axial length of approximately three-quarters of an inch and sixty-three of the metallic discs **2** having both surfaces undercut or stepped and two end metallic discs **5** and **10** each having a single undercut surface. The metallic discs **2**, **5** and **10** may be fabricated from titanium or stainless steel and specifically must have approximately the same temperature coefficient of expansion as the glass cylinders **1**. As indicated above other combinations of metal and glass may be employed to achieve this result.

Secured in the apertures **3** of the metallic discs **2** are hollow cylinders **4** employed to electrostatically shield the discharge region from whatever charge may accumulate on the inner periphery of the hollow glass cylinders **1**. The metallic cylinders are all of the same internal diameter except, preferably, for a hollow metallic cylinder **6** whose associated disc is to be connected to the approximate half voltage point on a voltage divider employed to provide appropriate accelerating voltages to the discs when the system is operational. The cylinder **6** is of lesser diameter than the remaining cylinders and is employed to minimize spontaneous discharge currents upon application of high voltage to the beam tube. As previously indicated, on a one and one-half million volt machine the utilization of the lesser diameter disc **6** reduces the spontaneous discharge current from about 30 microamperes to less than one microampere and if still further reduction is desired similar discs may be located at the one-quarter and three-quarter voltage points along the length of the tube. It is to be understood that improvement in operation relative to reduction in spontaneous currents results even if the metallic cylinders are eliminated and the aperture of the central disc is smaller than the rest. The results are not as good as when the cylinders are employed but one acceptable in many cases depending upon the number of discs employed and the voltage across the tube.

It would appear that the function of the metallic cylinder **6** is to accumulate the avalanche discharge which occurs in the conventional prior art tubes when the voltage is applied too rapidly. Each electron upon striking one of the metallic discs and/or its associated hollow metallic cylinder causes additional electrons to be emitted

and an avalanche effect occurs. The number of electrons emitted from each disc in response to an electron impinging thereupon raised to, in this case, the sixty-third power provides an indication of the total number of electrons that would occur in such a system. The disc **6**, located at the half-voltage point, which is usually half way down the length of the tube, intercepts the spontaneous current to that point. Thus, the current is reduced by a factor raised to approximately the thirty-first power. This is believed to be the basis of the mechanism. However, it is not intended to limit the invention to a specific theory since this fact has not been investigated fully. In order for the cylinder **6** to be effective it must be of sufficiently small diameter to intercept most of the discharge current emitted from the region between the cylinder and the cathode region. A safe ratio of the internal diameter of cylinder **6** to the remaining cylinders is about one and one-half to two; that is, if two inch internal diameter metal cylinders are employed, the internal diameter of the cylinder **6** should be approximately one and one-half inches or less.

The assembly is provided with a generally square end flange **7** adjacent the target region of the tube and in contact with end disc **10**. A generally circular end flange **8** is provided adjacent the cathode end of the tube and is in contact with end disc **5**. A cathode assembly **9** is positioned atop, as viewed in FIGURE 1, the circular end flange **8** and is secured thereto by four polyester-impregnated, fiber glass cinch rods **11** which extend to the end plate **7** to secure the entire assembly together. Specifically, the ends of the rods **11** adjacent the anode end of the structure, pass through suitable apertures in the end plate **7** and are engaged by double nut arrangements **12** which securely lock the nuts to the rod. The rods extend upwardly, as viewed in FIGURE 1, and proceed through aligned apertures in the end plate **8**, annular spacer **14** and an end disc **16** of the cathode assembly **9**. A spring **17** is disposed over the end of each of the cinch rods and is positioned between washers **18** and **19**, the latter of which engages the upper surface of the end disc **16** of the cathode assembly. Again, a double nut arrangement is employed to lock the position of the nuts relative to the rods **11**. The springs **17** are employed to maintain a constant tension in the rods **11** so as to maintain a specific pressure along the length of the tube.

It is preferred not to employ threads on the polyester impregnated, fiber glass rod since these do not have the requisite holding strength and tend to strip. Therefore, and reference is now made to FIGURE 3 of the accompanying drawings, both ends of the rods have a section **22** of reduced diameter over which is slipped the end of a steel rod **23**. The rod **23** is pinned to the rod **11** by means of appropriate metallic pins **24** so as to rigidly secure the rods **11** and **23**. The nuts **21** and **12** engage the sleeve **23** at opposite ends of the rod **11** and therefore the nuts engage threads on a steel rather than a fiber glass member.

It will be noted that all of the metal discs **2** except the two end discs **5** and **10** are undercut at **27** on both of its surfaces between the inner and outer diameters of the hollow cylindrical glass members **1**. This arrangement is necessary for the particular method of fabrication employed. The end discs **5** and **10** are provided with undercuts **28** and **29** respectively at their surfaces which engage adjacent hollow cylindrical glass members **1**.

Proceeding now to a description of the method of fabrication of the apparatus illustrated in FIGURE 1, the cathode assembly is first assembled and then the entire tube stack is assembled as illustrated in FIGURE 1. The epoxy resin of the type previously indicated is now applied by means of a paint brush, eye dropper, spraying or other suitable means, at each junction of the outer region of contact of each glass cylinder **1** and each metallic disc 2. These locations are generally designated by the reference numeral 31. The material is now carried by capillary action into the interface region between the glass and metal members and flows until it reaches the undercut regions of the metal discs. The spacing provided by the undercut in the metal discs is sufficient to terminate the capillary action and therefore none of the resinous material proceeds past this point and into a region subject to bombardment by electrons or ions.

The entire assembly operation comprises the steps of assembling the tube and then applying the epoxy resin at appropriate locations and allowing the resin to cure at room temperature. There is no requirement for accurately applying the synthetic resin to specific locations on the glass cylinders and metal discs or curing the binder at elevated and uniform temperatures. Also, the specific materials employed do not require solvents in the interface region which can destroy the seal intended to be provided by the material. As a result of this method of fabrication, the time required for fabricating such a structure is materially reduced and is of the order of several hours. Further, the percentage of tubes which do not meet specifications is materially reduced over the methods of the prior art, and even though relatively unskilled personnel may be employed to perform the assembly operation.

In an alternative method of fabrication, a jig is provided having three vertical rods equally spaced about a circle having the same diameter as the metal discs 2. The rods extend between fixed bottom and top end plates and the glass cylinders and metal discs are stacked in alternate array, the stack resting on the bottom plate. The metal discs are accurately positioned by three point contact with the rods and the glass cylinders may be aligned by eye. The jig is provided with a third plate having three holes for snugly but slidably receiving the three rods. This latter plate is quite thick so that it maintains an accurate alignment with the rods. The slidable plate is disposed between the top of the stack of cylinders and discs and the top fixed plate. When the stack is completely assembled the slidable plate is pressed downward to rigidify the stack. Epoxy resin is now applied to the juncture of the upper surfaces of the metal discs and the glass cylinders and the resin is allowed to dry for a short period. The stack and jig are now turned over and the resin is applied to the now upper surfaces of the discs at their juncture with the glass cylinders. After substantially complete curing of the resin, the jig is disassembled, the stack removed and the cathode assembly and cinch rods applied to complete the mechanical assembly.

While I have described and illustrated one specific embodiment of my invention, it will be clear that variations of the details of construction which are specifically illustrated and described may be resorted to without departing from the true spirit and scope of the invention as defined in the appended claims.

I claim:

1. A high-vacuum, high-voltage electron and ion beam acceleration tube comprising a plurality of centrally apertured thin metallic discs, a plurality of hollow glass cylinders having approximately the same temperature coefficient of expansion as said discs, said discs and cylinders being arranged in interleaved and abutting relationship along a common axis to provide a columnar structure, said metallic discs being undercut along both surfaces over an area defined by a radius greater than the internal diameter and less than the external diameter of said glass cylinders, said discs and cylinders being bonded together by a room-temperature-curing epoxy resin which extends across each interface defined by the abutting surfaces of said discs and cylinders, said interfaces terminating at the undercut area of said discs, said abutting surfaces being dimensioned and finished so as to support spread of the uncured epoxy resin by capillary action across the entire interface between said abutting surfaces, a pair of end plates contacting opposite ends of said columnar structure, cinch rods extending between said end plates, and means for tensioning said cinch rods to compress said columnar structure.

2. The combination according to claim 1 further comprising a plurality of hollow metallic cylinders, said cylinders being disposed in the apertures in said discs and secured thereto so as to be substantially coaxial with the axis of said columnar structure, all of said metallic cylinders having the same internal diameter except the metallic cylinder located approximately at the half-voltage point along said tube, said last mentioned metallic cylinder having an internal diameter approximately 25% less than the internal diameter of the remainder of said metallic cylinders.

3. The combination according to claim 1 further comprising a plurality of hollow metallic cylinders, said cylinders being disposed in the apertures in said discs and secured to said discs so as to be substantially coaxial with the axis of said columnar structure, all of said metallic cylinders having the same internal diameter except the metallic cylinder located approximately at the half-voltage point along said tube, said last mentioned metallic cylinder having an internal diameter substantially less than the internal diameter of the remainder of said metallic cylinders.

4. A high-vacuum, high-voltage electron and ion beam acceleration tube comprising a plurality of centrally apertured metallic discs, a plurality of hollow glass cylinders, said discs and said cylinders being arranged in interleaved and abutting relationship along a common axis to provide a columnar structure, said discs being bonded to said cylinders along the interfaces therebetween, a plurality of hollow metallic cylinders secured to said discs so as to be substantially coaxial with the axis of said columnar structure, all of said metallic cylinders having the same internal diameter except the metallic cylinder located approximately at the half voltage point along said tube, said last mentioned metallic cylinder having an internal diameter substantially less than the internal diameter of the remainder of said metallic cylinders.

5. A high-vacuum, high-voltage electron and ion beam acceleration tube comprising a plurality of centrally apertured metallic discs, a plurality of hollow glass cylinders, said discs and said cylinders being arranged in interleaved and abutting relationship along a common axis to provide a columnar structure, said discs being bonded to said cylinders across each interface therebetween, all of said discs having the same internal diameter except one of the discs located at approximately the one-half voltage point along said tube, said one disc having an internal diameter substantially smaller than the internal diameter of the remainder of said discs.

References Cited by the Examiner

UNITED STATES PATENTS

2,460,201	1/49	Trump et al.	313—313
2,517,260	8/50	Van de Graaff et al.	315—15
2,680,814	6/54	Robinson	313—85

FOREIGN PATENTS

665,998	2/52	Great Britain.

GEORGE N. WESTBY, *Primary Examiner.*

ARTHUR GAUSS, *Examiner.*