Sept. 5, 1950 J. G. TRUMP ET AL 2,521,426

HIGH-VOLTAGE EVACUATED ACCELERATION TUBE FOR INCREASING THE TOTAL VOLTAGE AND VOLTAGE GRADIENT THEREOF

Filed March 16, 1949 2 Sheets-Sheet 1

Fig. 1

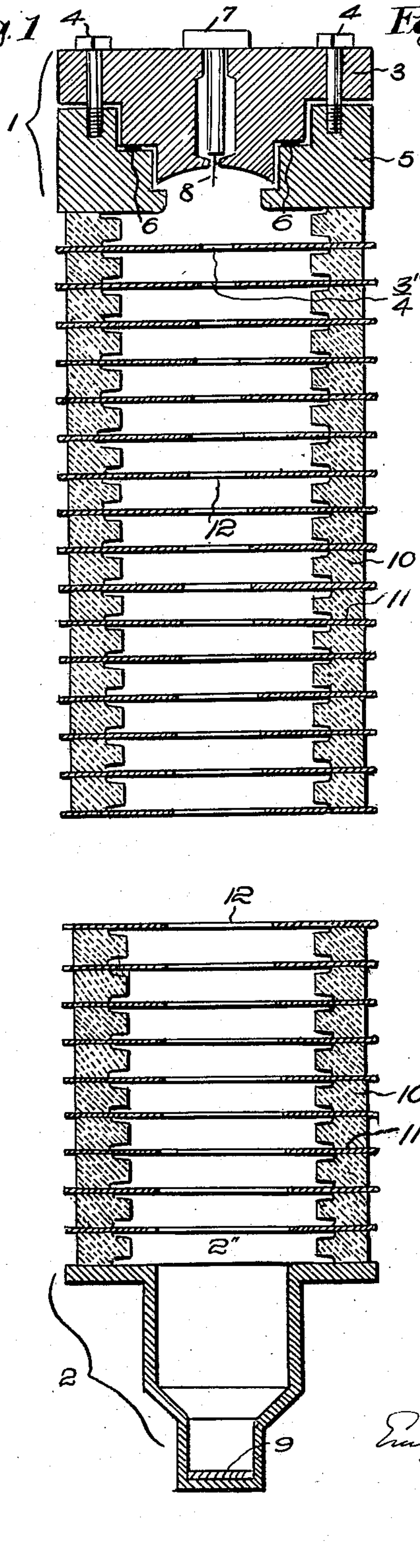

Fig. 2

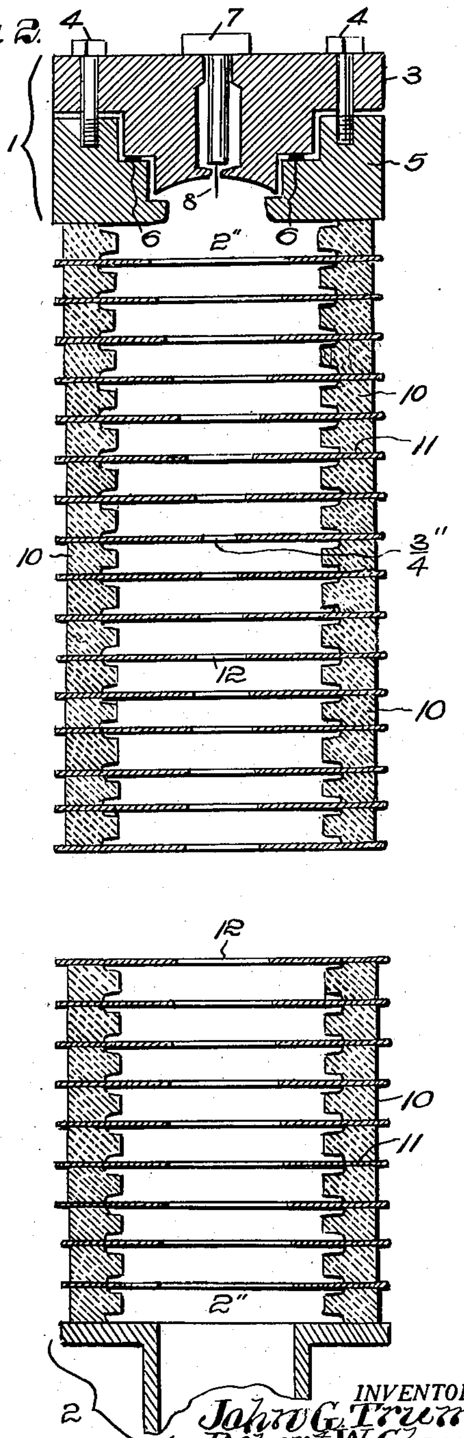

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Fig. 3.

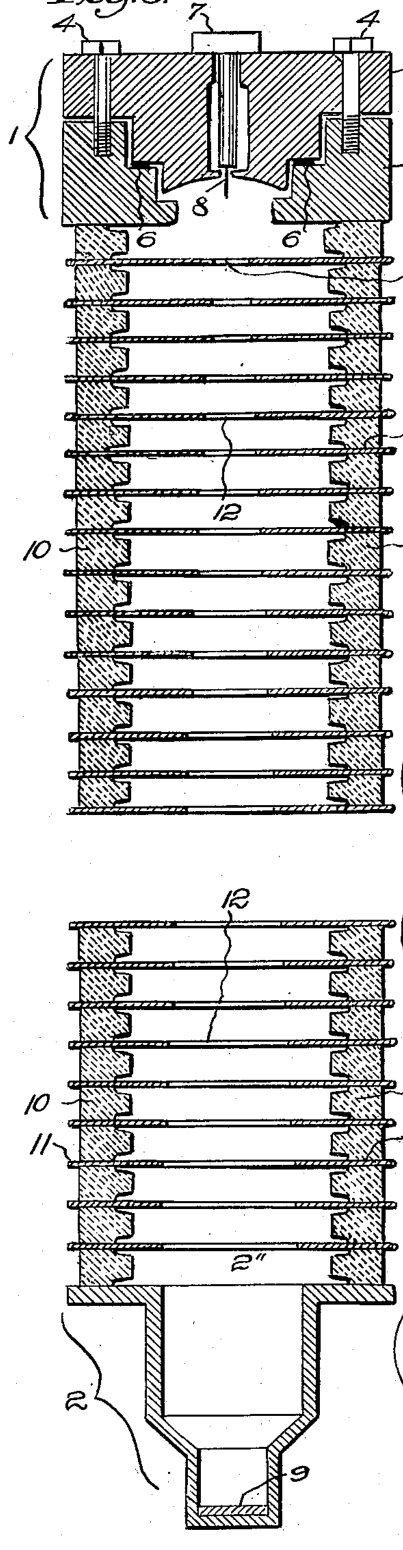


Fig. 4.

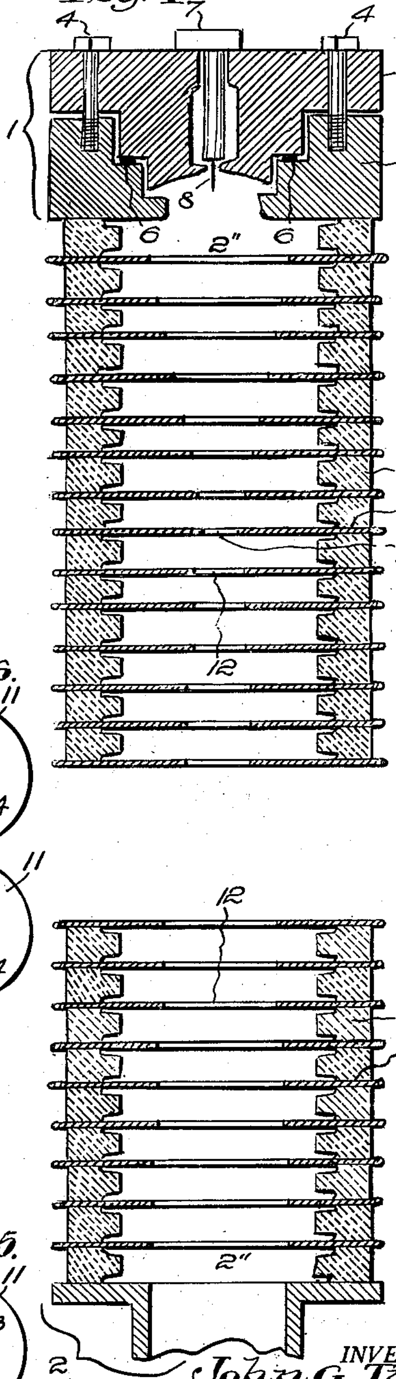


Fig. 6.

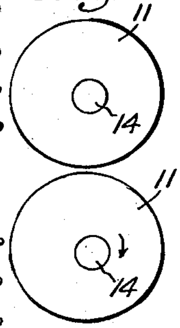
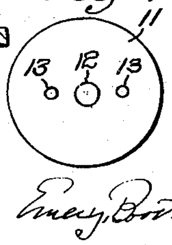


Fig. 5.



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UNITED STATES PATENT OFFICE

2,521,426

HIGH-VOLTAGE EVACUATED ACCELERATION TUBE FOR INCREASING THE TOTAL VOLTAGE AND VOLTAGE GRADIENT THEREOF

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12 Claims. (Cl. 250—27.5)

1

This invention particularly relates to evacuated, high-voltage, acceleration tubes of unusual voltage strength and compactness, for the purpose of increasing the total voltage and the voltage gradient that can be applied thereo.

In order that the broad principle of the invention may be readily understood, we have in the accompanying drawings disclosed several embodiments or representations of a structure or apparatus indicative of the invention and by which the invention may be practiced, and we shall in the ensuing specification describe merely such preferred embodiments of the novel acceleration tube, without limiting ourselves to such type of tube, nor merely to the disclosed embodiments thereof. We shall also herein set forth, but without limiting ourselves thereto, the best ways known to us for practicing our invention.

In the United States patent to Trump and Cloud, No. 2,460,201, dated January 25, 1949, there is disclosed an acceleration tube, or type of electronic tube, comprising or including a series of metallic disk or diaphragm electrodes alternating with annular members of glass or other suitable insulating material. The acceleration tube herein disclosed is or may be of the same general construction as that shown in the said patent, and preferably, as disclosed and claimed in such patent, we join the metallic disk or diaphragm electrodes and the alternating insulating annular members with a thermo-plastic or thermo-setting film, which film constitutes the vacuum-sealing and mechanical bond between such insulating annular members of glass or other suitable insulating material, and the said alternating metallic electrode disks or diaphragms of which the envelope of the high-voltage accelerating tube or other type of electronic tube is composed and which is provided with suitable cathode and anode assemblies.

Our present invention is, however, not concerned particularly with or limited to the manner or means for joining the metallic electrodes and the insulating annular members to constitute the envelope of the tube, but is concerned with means for increasing the total voltage which can be applied to the tube for the acceleration of particles to high energies and for increasing the voltage gradient which can be applied along the column of such tube for the progressive acceleration of charged particles to high energies. Our invention, otherwise stated or as another aspect thereof, is directed to means for reducing unwanted currents in the operation of such acceleration tubes.

Ever since the discovery of X-rays by Roentgen

2

in 1895 there have been persistent efforts to increase the voltage which could be applied to acceleration tubes. The effect of higher voltages is to increase the penetrating power and intensity of the radiation. X-rays produced by several million volts are more suitable for the irradiation of deep tumors in cancer therapy and are capable of quick radiographic examination of heavy metal sections. Such high-voltage acceleration tubes are needed also for the acceleration of electrons and positive ions in a variety of pure and applied research undertakings, including the investigation of the structure of the atomic nucleus.

Multi-stage acceleration tubes capable of operating with voltage gradients of one-million volts per foot of column have been successfully built for two-million volt operation. These voltage gradients along the column of an evacuated tube accelerating substantial electron or positive-ion currents are far in excess of those thus far common to the art.

The results thus far accomplished have required very extended and long continued research on the mechanism of voltage insulation in high vacuum, on the electrical and mechanical properties of materials used in acceleration tubes, and on the design and technique of fabrication, and respecting the performance of such tubes. Such extended and lengthy research has resulted in important improvements for which applications are now pending in the United States Patent Office in the names of ourselves or of one of us, as well as in the said Patent No. 2,460,201, issued to ourselves, and also in an application of Dr. Van de Graaff and Dr. Buechner with whom we have been associated in the researches referred to.

One of the limitations in the application of voltage to an acceleration tube is reached when high electron currents are developed spontaneously within the tube. These currents often take the form of transients, sometimes referred to as "dark currents," and our researches have led us to believe that they are due to the multiplication of some initial electrons by a series of collisions with the successive metallic disk or diaphragm electrodes of the acceleration tube, including the end electrodes thereof. We have, as the result of our researches, concluded that secondary emission and high-field electron emission characteristics of the electrode surfaces within the tube play an important role in determining the voltage at which such transients or "dark currents" appear as well as the severity thereof.

Our researches in this connection have also been directed at improving our understanding of fundamental mechanisms by which particles are released from metals under the influence of high electric fields and bombardment by electrons, positive ions and photons.

Multi-stage acceleration tubes herein referred to have, as above stated, been constructed of a series of metallic electrode disks or diaphragms spaced apart by the alternating insulating annular members of glass, porcelain or the like. Such metallic electrodes perform the function of accelerating and focusing, and have the advantage that the electric gradient on the metal surface thereof is kept at a minimum.

The said disk or diaphragm electrodes have been constructed as rings or annuli; that is to say, they have been provided with an axial hole therethrough, and, as disclosed, for example, in our said Patent No. 2,460,201, the said axial holes have all been of the same shape and area. Such metallic electrodes have been identical with each other in shape and size throughout the length of the acceleration tube, and the insulating annular members of glass, porcelain or the like have also been identical with each other. The said electrode disks or diaphragms have been thin and the annular insulation members have been of relatively larger thickness so that next adjacent metallic electrode disks or diaphragms have been separated from each other in the preferred construction by a substantial part of an inch or even more in tubes of larger diameter. The outer edges of the metallic electrode disks or diaphragms and the annular insulation members have been substantially coterminous, but the inner edges of the metallic electrode disks or diaphragms have extended inward beyond the inner edges of said annular members substantially to the extent indicated in our Patent No. 2,460,201 and provide shielding as explained in said patent and in our co-pending applications.

While our present invention is not limited in its application to acceleration tubes such as that just described, the principle of our present invention will be apparent upon a consideration of the characteristics of such acceleration tubes, taken with the novel features of our invention now to be set forth.

As a result of our said researches and investigations, we have discovered that by progressively or otherwise varying the diameter of the axial holes in the different metallic electrode disks or diaphragms of the tube with relation to each other, we thereby reduce the tendency of an initial charged particle to multiply itself many times over en route from the cathode of the acceleration tube to the anode thereof by the release of secondary electrons, photons and positive ions.

Such multiplication of an initial charged particle is an exponential process similar to that encountered in the well known "multiplier tube." A typical high-voltage acceleration tube may be regarded as a "multiplier tube" with an extraordinarily large number of electrodes and therefore could be particularly effective in the development of unwanted transient currents of very high peak values, and this our researches and experiments have shown to be the case.

Instead of having the metallic electrode disks or diaphragms all provided with the same size and area of axial hole therethrough, we progressively or otherwise change the diameters and areas of the said axial holes of the metallic electrode disks or diaphragms, and therefore avoid to a large extent the possibility of an initial electron multiplying itself through successive collisions with intervening metallic electrode disks or diaphragms while en route from the cathode to or toward the anode of the acceleration tube.

This construction and manner of operation we have discovered to be also effective in avoiding such multiplication of positive ions which may be traveling toward the cathode, and of photons which are capable of causing photoelectron emission back near the cathode. Likewise positive ions will be accelerated by the electric field toward the cathode, and should they impinge upon a metallic disk or electrode, they too will cause the secondary emission of electrons which are then accelerated toward the anode.

In certain cases we have secured the desired effect by progressively increasing the diameters of the said axial holes from the smallest value at the cathode end to the largest value at the anode end of the tube. In other tubes constituting embodiments of our invention, we have started with a fairly large axial hole in the metallic electrode disk or diaphragm next to the cathode end of the tube and have gradually reduced the diameter and area of the axial holes of successive metallic electrode disks or diaphragms to the smallest value at an electrode disk or diaphragm which lies intermediate between the cathode and the anode of the tube and then again progressively increased the diameter and area of such holes to the largest value at the anode end of the tube. We also, in other embodiments of our invention, have changed the diameters or areas of the axial holes of the metallic electrode disks or diaphragms stepwise; that is to say, we have provided two, three or more electrode disks or diaphragms having a given diameter of axial hole therethrough at or near the cathode end of the tube, and then have made a discreet change by increase or by decrease to a new diameter in certain succeeding electrode disks or diaphragms of the tube, and so on throughout the tube to or toward the anode end.

While we have in preceding paragraphs referred to several embodiments of our invention, it is to be understood that we are not limited thereto. We have chosen in the drawings to illustrate five different embodiments of our invention and they will be hereinafter specifically referred to.

In all of the cases indicated, we have found that "dark currents" or transients of the type referred to have been substantially reduced at a given voltage and that the permissible voltage to give satisfactory operation has been significantly increased.

By progressively or otherwise changing, lengthwise the acceleration tube, the geometry of the electrode disks or diaphragms with respect to the diameter and area of the axial holes therethrough in accordance with our invention, we reduce the possibility of exponential multiplication of random and scattered charged particles, and we have found that we have achieved a fundamental change in the high-voltage acceleration tube art, thereby making possible both higher total voltages and higher voltage gradients along the column of the acceleration tube, and thereby perform an important function which has not hitherto been realized or achieved in the art.

Without here setting forth all the different embodiments of our invention, we have in the accompanying drawings set forth five embodiments thereof, and we will now describe them in detail.

Referring to the drawings:

Fig. 1 is a vertical, longitudinal, central section, with an intermediate part broken away, taken through an acceleration tube embodying our invention, and wherein the axial circular holes through the metallic electrode disks or diaphragms gradually increase in diameter from the cathode end to the anode end of the tube;

Fig. 2 is a sectional view similar to Fig. 1, but disclosing a construction wherein the axial circular holes in the metallic electrode disks or diaphragms gradually decrease in diameter to an electrode disk or diaphragm intermediate the cathode and the anode assemblies, herein about one-quarter way down the tube column, and then gradually increase in diameter to the maximum area at the anode end of the acceleration tube;

Fig. 3 is a sectional view generally similar to Fig. 1, but showing a construction wherein the diameters of the axial circular holes through electrode disks or diaphragms increase in a series of steps, each step including a small number of electrodes having the same diameter of axial holes;

Fig. 4 is a sectional view generally similar to Fig. 2, but showing a construction wherein the axial circular holes through the electrode disks or diaphragms are of the largest diameter at the cathode end of the tube and uniformly decrease in diameter as in Fig. 2, and then increase in steps to the anode end, each such step including several electrode disks or diaphragms having the same diameter of axial circular holes; and

Figs. 5 and 6 are plan views of modified constructions of the metallic electrode disks or diaphragms.

Referring to the drawings illustrating several selected embodiments of the structure or apparatus of the invention, but to which our invention is not limited, and first referring to Fig. 1, there is shown therein the assembly of a sealed-off or continuously pumped acceleration tube of a two-million voltage or greater having as a part thereof a cathode assembly indicated generally at 1, and an anode assembly indicated generally at 2. The said acceleration tube is in practice mounted within a high-voltage generator in such a way that the cathode end is within the high-voltage terminal and the tube column is within the column of the generator itself.

The cathode assembly is herein shown as comprising a removable cathode head 3 secured by bolts 4 to the body portion 5 of the said cathode assembly, there being a suitable circular gasket 6 between said parts 3 and 5. A suitable insulated filament lead 7 is provided, having a suitable filament 8, such as tungsten, which may be such as is disclosed in our said Patent 2,460,201. The anode assembly 2 of suitable construction is provided with an anode target 9 preferably of gold, as disclosed in one of the pending applications hereinbefore referred to.

The column or envelope of the acceleration tube is composed of a multiplicity of alternating glass, porcelain or other annular insulation members 10 and metallic electrode disks or diaphragms 11 which desirably are bonded together by a plastic film, as fully disclosed and claimed in our said Patent 2,460,201, but which film is not indicated in the drawings because of drafting space limitations. The said annular insulation members 10 and the metallic electrode disks or diaphragms 11 lie accurately placed in planes perpendicular to the axis of the acceleration tube and are placed at equal distances apart. For example, the said electrode disks or diaphragms 11 are desirably placed one-third of an inch apart. The insulating column of the acceleration tube is shown as transversely broken away, because of drafting space limitations.

While our invention is in no wise limited to the disclosed size and relative proportion of parts, or the number of annular insulation members and electrode disks or diaphragms, the insulating column of the acceleration tube shown in Fig. 1, is in the present instance, in practice, twenty-four inches long, and includes thirty-four annular insulation members or rings 10, there being such an insulation member or ring 10 next to the cathode assembly 1 and another next to the anode assembly, both desirably bonded to said assemblies respectively, as in our said Patent 2,460,201.

There are, in practice, in the acceleration tube represented in Fig. 1, thirty-three metallic electrode disks or diaphragms 11 respectively alternating throughout the said acceleration tube with the annular insulation members 10. The outer edges of the said annular insulation members 10 and of the metallic electrode disks or diaphragms 11 are substantially, though not exactly, coterminous, and in the example of the invention represented in Fig. 1, the column or envelope of the acceleration tube has an extreme outside diameter of four and a half inches.

The diameter of the axial holes through the annular insulation members or rings 10 is uniform throughout the tube and is such that the internal diameter of the insulating column at the inner wall at said annular insulation members 10 is three inches. Each annular insulation member 10 is nearly three-quarters of an inch thick in said disclosed embodiment of the invention.

We have referred to the outer edges of the annular insulation members 10 and the metallic electrode disks or diaphragms 11 as substantially coterminous. Actually the outside diameter of the said electrode disks or diaphragms 11 is, in the disclosure referred to, four and three-quarters inches as compared with the said four and one-half inch outside diameter of the annular insulation members 10, and each of said electrode disks or diaphragms 11 has a thickness of .050 of an inch.

Each of the said metallic electrode disks or diaphragms 11 is provided with an axial hole therethrough, to which the numeral 12 is generally applied. As already stated, in prior constructions the axial holes of the entire series of electrode disks or diaphragms were of the same diameter and area.

For the reasons hereinbefore stated (that is, for the purpose of increasing the total voltage that can be applied to the acceleration tube for the acceleration of particles to high energies, and for the purpose of increasing the voltage gradient which can be applied along the column of the tube for the progressive acceleration of charged particles to high energies), the electrode disks or diaphragms 11 are, in accordance with our present invention, arranged with progressively varying internal geometry.

In Fig. 1, the axial circular holes 12 progressively increase in size from a smallest value at the cathode end of the acceleration tube to a larger value at or near the anode end thereof. In the construction shown in Fig. 1, the diameter of the axial circular hole 12 in the topmost electrode disk or diaphragm is three-quarters of an inch, and the size of said axial holes 12 gradually and uniformly increases throughout the entire series of electrode disks or diaphragms to a diameter of the circular axial hole of the electrode disk or diaphragm nearest the anode end of two inches. Other dimensions may be used within the scope and purpose of our invention, as the important feature is that the inner edges of the metallic disks or diaphragms do not lie exactly one over the other, but progressively extend further inward or outward, and this is also true of the other embodiments of our invention herein disclosed.

Another embodiment of the invention is represented in Fig. 2, wherein the structure is the same as in Fig. 1, excepting with respect to the diameters of the axial circular holes 12 through the respective electrode disks or diaphragms 11 of said Fig. 2.

In the structure shown in Fig. 2, the axial circular hole 12 through the topmost electrode disk or diaphragm 11 is two inches, and in successive electrode disks or diaphragms 11 the size of the axial holes 12 thereof gradually decreases to three-quarters of an inch in diameter at the eighth electrode disk or diaphragm from the cathode end of the tube, and from there on to the anode end of the tube, the diameter of the axial circular holes 12 gradually increases to two inches. Thus in Fig. 2 the diameter of the axial circular holes gradually decreases to a point substantially one-quarter of the distance between the cathode assembly and the anode assembly and from there on gradually increases as just above stated. We are not, however, limited to this location of smallest axial opening.

The construction shown in Fig. 3 is in all respects similar to that shown in Fig. 1, excepting with respect to the diameter of the axial circular holes 12 through the electrode disks or diaphragms 11. In the construction shown in Fig. 3, the diameter of the axial circular holes 12 varies in discreet steps, and in the construction shown in said Fig. 3 each of the said steps includes three disks or diaphragms, the diameter of whose axial circular holes 12 is the same. Thus, in the embodiment of the invention shown in Fig. 3, there are eleven steps each having three successive electrode disks or diaphragms 11 and, as stated, the diameter of the axial circular holes 12 of such electrode disks or diaphragms is the least in the first step of three such disks or diaphragms all having the same diameter of axial circular hole 12, is very slightly greater in the next step of three disks or diaphragms 11 all having axial circular holes 12 of such slightly larger diameter, and so on throughout all the eleven or other number of steps (eleven such steps being indicated in Fig. 3), the diameter of the axial holes 12 through the electrode disks or diaphragms of each such step being very slightly greater than in the next preceding step.

In the embodiment of the invention shown in Fig. 4, the construction is the same as in Fig. 2, excepting with respect to the diameter of the axial circular holes 12 of the disks or diaphragms 11. In the construction shown in Fig. 4, the diameter of the axial circular holes 12 gradually and uniformly decreases (though the decrease may be in steps as in Fig. 2), from the largest diameter of two inches of the topmost electrode disk or diaphragm 11 nearest the cathode assembly to the eighth disk or diaphragm 11 from said electrode assembly and then the diameter of the axial circular holes 12 from there on to the anode end of the tube increases in steps, each step including three or four disks or diaphragms 11, and all the disks or diaphragms 11 of each step have the same diameter of axial circular holes 12 among themselves, but the diameters of said axial circular holes 12 slightly increase in each succeeding step or group to the maximum diameter of two inches at the anode end of the acceleration tube. We are not, however, limited to this location of smallest axial opening.

With respect to the construction shown in Figs. 2 and 4 wherein, through a portion of the tube extending from the cathode end, the diameters and areas of the axial holes in the metallic electrodes decrease instead of increasing, it will be observed that in such constructions the inner edges of the metallic disks or diaphragms do not lie directly one over another, but terminate at different distances from the axial center of the tube.

Therefore positive ions, for example, at some point, such as the inner edge of a metallic disk or diaphragm where, or near where, the axial holes are of the least area and diameter, would be accelerated toward the cathode end of the tube but would "fall" or pass free of the disk or diaphragm electrodes in transit, and hence would have reduced opportunity for producing secondary electrons by impact, and moreover any electrons originating in the referred to portion of the tube would tend to be collected by the succeeding disks or diaphragms in that portion of the tube, since such metallic disks or diaphragms progressively jut out more and more toward the axial center of the tube.

Although we have herein given precise dimensions of parts, our invention is not limited thereto, and in other embodiments of the invention other dimensions of the parts may be employed within the scope of the invention.

In those embodiments of our invention thus far specifically described, each of the electrode disks or diaphragms is provided with an axial hole only, these holes varying in area or diameter as hereinbefore described. In the case of certain of the electrode disks or diaphragms, especially those in which the axial holes are of the least area or diameter, and where the tube is intended for the acceleration of positive ions, the reduction of the area of axial holes does or may cut down the pumping speed of the tubes.

Positive ion acceleration tubes usually have hydrogen or deuterium gas escaping into them from the ion source, so that pumping speed is an important consideration. Therefore, in those diaphrams where the area of the axial hole is actually rather small, we provide one or more additional small holes to assist in maintaining pumping speed. Such additional hole or holes, however, has or have little effect on the operation of the diaphragm or diaphragms as an electrostatic lens.

In Fig. 5 we have represented in plan view one of the electrode disks or diaphragms 11, such as a diaphragm represented in Fig. 2 as having an axial hole having a diameter of three-quarters of an inch. In such an electrode, and if desired in a number of the diaphragms of smallest diameter, we provide one or more additional small through-holes 13. In said figure, two such additional small holes are provided at opposite sides of the axial hole 12. We may provide one or more than two of the additional small holes and position them at any desired point.

In Figs. 1 to 4, the axial holes are all centrally and concentrically positioned and differ as described in diameter or area. While we prefer the constructions shown in Figs. 1 to 4, we may make the axial holes in the disks or diaphragms all of the same size or substantially the same size, but position them eccentrically with respect to the actual center of the said disks or diaphragms. We may vary such eccentricity by progressively advancing circumferentially in successive diaphragms or groups of diaphragms. That is to say, we change the orientation slightly of these holes. We may alternately advance and retard such eccentricity in successive diaphragms. The purpose of such construction is to trap sooner or later the non-axial charged particles, while the axial particles are focused and accelerated.

In Fig. 6 we have represented two diaphragm electrodes 11, and in each of them is represented an axial hole, but instead of making the said holes exactly concentric or central with respect to the exact axis of the diaphragm, they are eccentric with respect thereto, as indicated at 14. A comparison of the two diaphragms of this figure makes it evident that the eccentricity is slightly circumferentially advanced in the lower diaphragm with respect to the upper diaphragm. That is, the orientation is slightly changed. As stated, such variation of the eccentricity may be clockwise or contraclockwise.

Our invention comprehends increasing the voltage gradient which can be applied to an evaculated multiple-electrode tube for the acceleration of charged particles to high energies and of reducing stray currents in such a tube by markedly reducing the tendency for multiplication of stray charged particles because of secondary emission by collision with successive electrode diaphragm. We do this by providing a progressive variance with respect to each other of the holes in the electrodes through which the particles pass. Such progressive variance of the holes in the electrode diaphragms may be in size, shape or orientation. Respecting those forms of the invention wherein the diameters or areas of the axial openings through the metallic electrode disks decrease from the cathode end of the tube onward, as in Figs. 2 and 4, our invention is not limited to constructions wherein the smallest axial opening is at any particular point intermediate the cathode and the anode, the invention being of broad scope in this respect. We believe, however, that for both electron and positive-ion acceleration tubes, the most constricted region should be kept nearer to the cathode end of the tube, but the scope of our invention is not to be so defined.

Having thus described several embodiments of the invention, it is be understood that although specific terms are employed, they are used in a generic and descriptive sense and not for purposes of limitation, the scope of the invention being set forth in the following claims.

We claim:

1. An evacuated high - voltage acceleration tube for increasing the voltage and voltage gradient which can be applied along the insulating envelope thereof in effecting the progressive acceleration of charged particles to high energies and for reducing the tendency to or opportunity for producing secondary particles such as electrons, positive ions and photons in said tube, comprising a multiplicity of metallic ring-like electrode members and alternating insulating ring-like members only, bonded together in face-to-face relation to constitute the insulating envelope thereof, and having at its respective ends cathode and anode assemblies, the areas or diameters of the axial holes of the said metallic electrode members of said tube varying among themselves.

2. An evacuated high - voltage acceleration tube in accordance with claim 1, wherein the said variation of the areas or diameters of the axial holes of the metallic electrode members is a progressive increase from a smallest value substantially at the cathode end of the tube to a larger value toward the anode end thereof.

3. An evacuated high-voltage acceleration tube in accordance with claim 1, wherein the said variation of the areas or diameters of the axial holes of the metallic electrode members is a progressive increase by groups of said metallic electrodes from a smallest value substantially at the cathode end of the tube to a larger value toward the anode end thereof.

4. An evacuated high-voltage acceleration tube in accordance with claim 1, wherein the said variation of the areas or diameters of the axial holes of the metallic electrode members is a progressive decrease from a smallest value substantially at the cathode end of the tube toward the anode end thereof.

5. An evacuated high-voltage acceleration tube in accordance with claim 1, wherein the said variation of the areas or diameters of the axial holes of the metallic electrode members is a progressive decrease from a smallest value substantially at the cathode end of the tube toward the anode end thereof to an intermediate point between the said cathode and the anode assemblies followed by a progressive increase substantially to the anode end.

6. An evacuated high-voltage acceleration tube in accordance with claim 1, wherein the said variation of the areas or diameters of the axial holes of the metallic electrode members constitutes an eccentric variation in a circumferential direction of the position of the said axial holes of said metallic electrode members with respect to the longitudinal axis of the said acceleration tube.

7. An evacuated high-voltage acceleration tube for increasing the voltage and voltage gradient which can be applied along the insulating envelope thereof in effecting the progressive acceleration of charged particles to high energies and for reducing the tendency to or opportunity for producing secondary particles such as electrons, positive ions and photons in said tube, comprising a multiplicity of metallic ring-like electrode members and alternating insulating ring-like members only, bonded together in face-to-face relation to constitute the insulating envelope thereof, and having at its respective ends cathode and anode assemblies, the areas or diameters of the axial holes of the said metallic electrode members of said tube varying among themselves, at least one of the metallic electrode members having substantially a smallest axial opening therein, being provided with at least one additional small through-hole to assist in maintaining pumping speed.

8. An evacuated high-voltage acceleration tube for the acceleration of particles to high energies

comprising a multiplicity of metallic ring-like electrode members and alternating insulating ring-like members constituting the insulating envelope thereof, the said tube having at its respective ends cathode and anode assemblies, the said tube, for the purpose of increasing the voltage and voltage gradient which can be applied along the insulating envelope thereof for the progressive acceleration of charged particles to high energies, having the axial holes of said metallic ring-like electrode members progressively increased in diameter from a smallest value at the cathode end of the tube to a larger value near the anode end thereof.

9. An evacuated high-voltage acceleration tube for the acceleration of particles to high energies comprising a multiplicity of metallic ring-like electrode members and alternating insulating ring-like members constituting the insulating envelope thereof, the said tube having at its respective ends cathode and anode assemblies, the said tube, for the purpose of increasing the voltage and voltage gradient which can be applied along the insulating envelope thereof for the progressive acceleration of charged particles to high energies, having the axial holes differentiated among themselves by reason of a gradual increase in size thereof from the cathode end to the anode end of the said tube.

10. An evacuated, multiple electrode, acceleration tube for the acceleration of electrons or positive ions to high energies, comprising a multiplicity of alternating insulation rings and metallic electrode disks only, bonded directly to each other throughout the tube, the diameters of the axial holes of the insulation rings being uniform throughout the tube, the said tube having a cathode assembly and an anode assembly bonded directly at opposite ends to the final insulation rings at said ends, the said electrode disks being each provided with an axial hole therethrough for the passage of charged particles, the areas or diameters of said axial holes of the said electrode disks only, being varied with respect to each other.

11. A cylindrical, evacuated, multiple electrode, tube for the acceleration of electrons or positive ions to high energies, comprising a multiplicity of insulation rings all of the same external diameter and internal diameter, and metallic electrode disks thinner than said insulation rings, and alternating with them and bonded directly to them throughout the said tube, the outer edges of said insulation rings and electrode disks being substantially co-terminous throughout the length of the said cylindrical acceleration tube, each of the said electrode disks being provided with an axial hole therethrough for the passage of charged particles, the areas or diameters of the said axial holes of the electrode disks being varied with respect to each other, the said cylindrical acceleration tube having a cathode assembly and an anode assembly respectively bonded to the terminal insulation rings at the opposite ends of the said cylindrical acceleration tube.

12. A cylindrical, evacuated, multiple electrode, tube for the acceleration of electrons or positive ions to high energies, comprising a multiplicity of insulation rings all of the same external diameter and metallic electrode disks alternating with them and bonded directly to them throughout the said tube, the outer edges of the said insulation rings and electrode disks being substantially coterminous throughout the length of the said cylindrical acceleration tube, each of the said electrode disks being provided with an axial hole therethrough for the passage of charged particles, the areas or diameters of the said axial holes of the electrode disks being varied with respect to each other, the said cylindrical acceleration tube having a cathode assembly and an anode assembly respectively bonded to the terminal insulation rings at the opposite ends of the said cylindrical acceleration tube.

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ROBERT W. CLOUD.

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