Feb. 16, 1960 R. W. CLOUD ET AL 2,925,504

HIGH-VACUUM PUMPS FOR HIGH-VOLTAGE ACCELERATION TUBES

Filed June 17, 1957 2 Sheets-Sheet 1

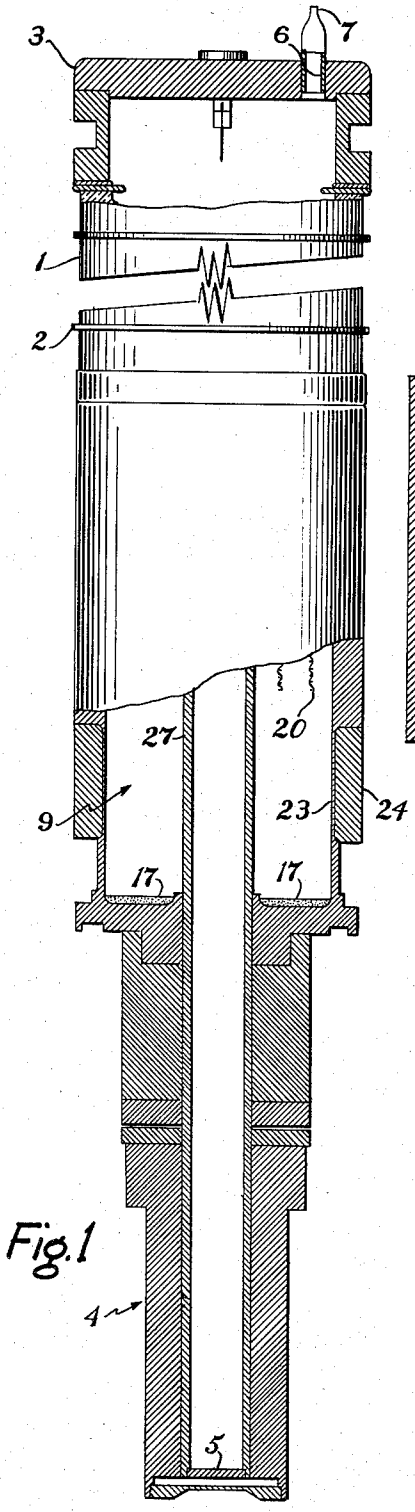

Fig. 1

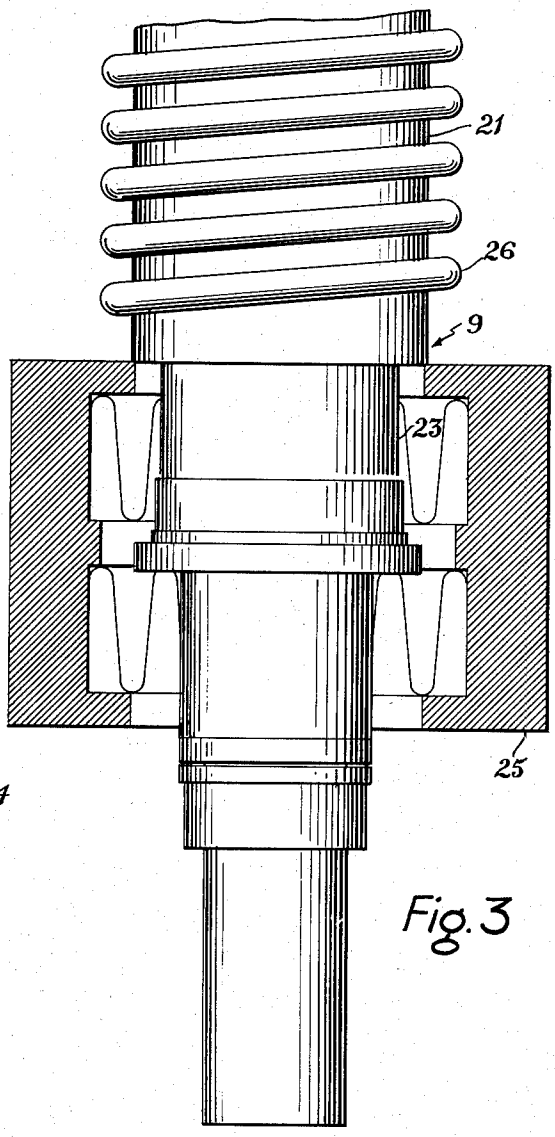

Fig. 3

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HIGH-VACUUM PUMPS FOR HIGH-VOLTAGE ACCELERATION TUBES

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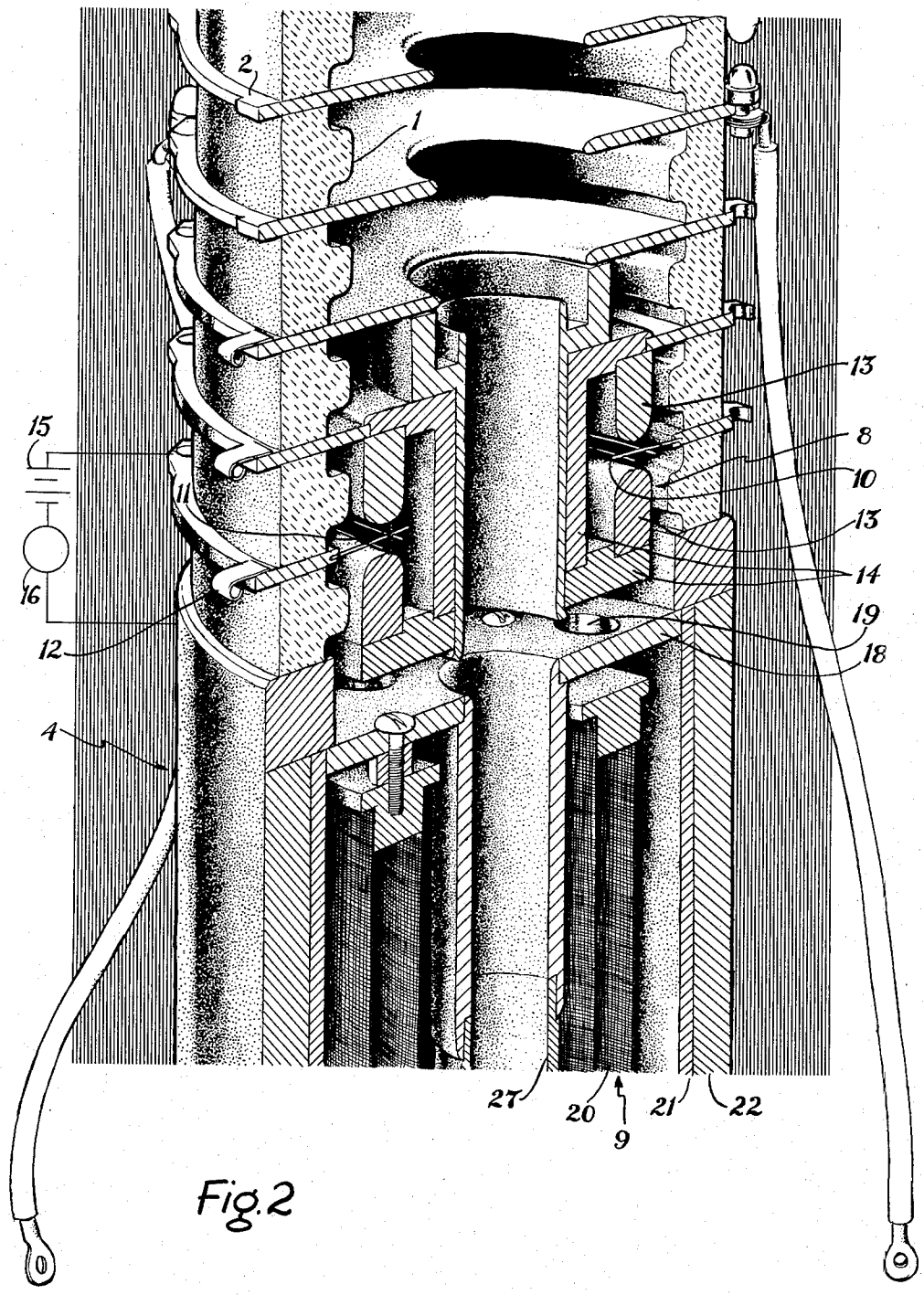

Fig. 2

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2,925,504

HIGH-VACUUM PUMPS FOR HIGH-VOLTAGE ACCELERATION TUBES

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15 Claims. (Cl. 313—7)

This invention relates to a new type of high vacuum pump which employs an active metal getter such as barium in combination with an activating agent such as ionization. In particular, the invention comprehends a getter-ion pump which forms an integral part of a particle acceleration tube. In one embodiment of the invention, heat for the evaporation of a barium getter is provided from a heat source outside the acceleration tube to be evacuated. In another embodiment of the invention, the amounts of barium available for evaporation are in excess of 10 grams. High-vacuum pumps constructed according to the invention are capable of maintaining a high vacuum in sealed-off acceleration tubes of the megavolt class. These tubes, in a sense, represent a difficult vacuum problem because they contain not only the gas ingredients of glass and metal, but also the vapors of the hydrocarbons used to form strong glass-to-metal joints between the multiple glass and metal materials.

Active metal getters such as evaporated barium do not absorb many organic materials so that active metals are not effective in maintaining a high vacuum in systems which are sealed with or contain organic materials. However, the combination of such a getter with an activating agent, such as ionization or heat, is effective in removing from an enclosed region, not only the common getterable gases, such as hydrogen, nitrogen, oxygen, and water vapor, but also the previously non-getterable gases including the noble gases (helium, argon, krypton, etc.) and certain molecules such as hydrocarbon vapors. In the case of the ungetterable compound molecules, the mechanism probably involves first their dissociation into the simple getterable ingredients. It may also involve, as it does in the case of the noble gases, the activation of the molecules without dissociation. Such activation, even though to a sub-ionization level, would tend to render these molecules capable of attachment to an active metal getter.

It has long been known that many substances such as barium, potassium, thorium, magnesium, and zirconium are capable of absorbing considerable quantities of ordinary gas molecules. The use of barium and other getters is a common device in the manufacture of radio tubes and other permanently sealed-off systems. These generally employ very small quantities of getter material, generally less than 10 or 100 milligrams.

It has likewise been understood for many years that the presence of ionization in an evacuated enclosure results in the absorption of residual gas, including even the noble gases which are not absorbed by an active metal getter alone. Such absorption of residual gas was noted in the old gas-filled X-ray tubes employing cold cathodes. These X-ray tubes derived their electron current through positive ion bombardment of the cathode, the positive ions being formed by collisions of the electrons in the beam with the residual gas molecules. In such tubes it was necessary to provide a source of gas to prevent the gradual cleanup of the tube into a non-operative high vacuum condition. Such cleanup in the presence of

ionization was also noted by many investigators using closed systems containing ionization gages as a means of measuring high vacuum pressure.

It is not believed, however, that the prior art contains descriptions of getter ion pumping devices particularly adapted to the evacuation of sealed-off systems wherein the rate of evolution of gas exceeds 10^{-7} millimeter-liters per second, whether due to the large size of the system or to gasket material or to organic cements or to other causes. Such systems include, but are not limited to, multiple-electrode high-voltage acceleration tubes having organic seals, which cannot be heated to conventional outgassing temperatures, and linear accelerator tubes, which may employ a type of metal gasket seal having a melting point too low to permit conventional outgassing techniques. Therefore, while in the following detailed description the invention is described with particular reference to a multiple-electrode high-voltage acceleration tube, the invention is not limited thereto, but includes other types of sealed-off systems wherein the rate of evolution of gas may exceed 10^{-7} millimeter-liters per second. One such system is the so-called "tandem" particle accelerator, wherein negative ions are accelerated towards a high-voltage terminal and then, after passing through a gaseous "stripper" region, are accelerated away from the terminal; the "stripper" region continuously evolves gas which must be pumped.

Vacuum devices may be divided into two categories: (1) those which are permanently sealed-off for the life of the device, and (2) those which are continuously pumped to maintain the high vacuum. The use of getter material has generally been confined to permanently sealed-off devices which have been very carefully outgassed and pumped down to a high vacuum prior to seal-off, and the function of the getter has been confined to absorbing the residual gases which remain after such outgassing, pumping, and seal-off. These preliminary steps of outgassing and pumping have been thought essential in connection with sealed-off devices, with the getter playing a subsidiary role. Both processes must be carried out with great care, and are particularly difficult in the case of systems containing electrodes at high potential, more specifically, in excess of 100 kilovolts. Such a high voltage device is hard to construct. They must maintain high vacuum over extended periods and great care is required in their manufacture. Metal for the electrodes often must be oxygen free and the electrodes often are outgassed prior to installation in the tube assembly. The assembly is subjected to vigorous heat treatment and operation prior to seal-off using high speed diffusion pumps and traps to collect the emitted gases. Furthermore, in order to free such substances of organic vapors, painstaking developments have been made of glass and metal which are mechanically compatible, which can be joined and still withstand the high temperature cycling required in the former outgassing procedure. The introduction of any source of vapor is scrupulously avoided, and even so the life of such tubes is often limited by gassiness, which may result from inadequate outgassing procedure.

Devices which cannot be outgassed for one reason or another have always been continuously pumped, presumably because the idea of a continuous evolution of gas within the container to be evacuated suggests a continuous pumping system. Accordingly, in the initial development of high-voltage acceleration tubes, wherein the high-energy charged particles release gases by bombardment of the solid surfaces within the tube, continuous pumping systems were always used. In the sealed-off acceleration tubes which were later developed, it was found necessary to take extremely elaborate steps to outgas and pump down the acceleration tubes prior to seal-off. Such

vigorous treatment reduces the evolution of gas within these acceleration tubes down to or below that prevalent in small radio tubes and accordingly either no getter is used, or only a small quantity such as that used in conventional radio tubes.

The idea of using an adequate amount of getter material coupled with an independent source of excitation and ionization for the permanent evacuation of unoutgassed high-voltage acceleration tubes has not been considered prior to this invention. The reasons for this include, in addition to those hereinbefore mentioned, the undesirable effects resulting when the getter material is exposed either to high energy charged particles or to high voltage gradients. Moreover, if this idea had been proposed earlier, it would have been rejected as unworkable. It has been well known in the art that if the cases normally entrained in an unoutgassing cubic centimeter of copper are released, the quantity of gas thus released will amount to hundreds of cubic centimeters at atmospheric pressure. In accordance with the invention, a sufficiently large quantity of getter material is used to absorb gases during the life of the evacuated device, and the getter material is shielded from the high energy charged particles and from intense electric fields. Moreover, the getter material is not permitted to become overheated, whereby the tendency of the getter to migrate is minimized. In a preferred embodiment of the invention, the getter material is vaporized so as to form an extended surface by a heat source external to the chamber to be evacuated.

In accordance with the invention, it is possible to combine materials without excessive regard for their outgassing properties. Glass and materials may be chosen for their electrical characteristics and may be joined with an organic seal or low-melting-point solder or metal gasket. The tube need not be subjected to any temperature cycling or operated prior to seal-off. Before the pump of the invention is used, the tube need be evacuated only with a mechanical pump to a pressure of 10^{-2} millimeters of mercury or thereabouts. Even this use of a mechanical forepump may be eliminated, since the pump of the invention is capable of operating even at atmospheric pressure. Moreover, the invention is applicable to tubes characterized by very high gradient requirements such as acceleration tubes, operating at a total voltage of the order of several million volts and with electrical gradients lengthwise of 500 kilovolts per foot or more.

The invention may best be understood from the detailed description thereof having reference to the accompanying drawing in which:

Fig. 1 is a side view, partly in longitudinal central section and partly broken away, of a multiple-electrode high-voltage acceleration tube incorporating a high vacuum pump in accordance with the invention;

Fig. 2 is a perspective view of a longitudinal central section of a portion of the acceleration tube of Fig. 1; and

Fig. 3 is a side view similar to that of Fig. 1 but showing the evaporation device by means of which the getter is evaporated in accordance with the invention.

Referring to the drawings, there is shown in Figs. 1–3 an acceleration tube of the general type disclosed in United States Patent No. 2,460,201 to Trump and Cloud and comprising a multiplicity of alternating insulating rings **1** and apertured electrode disks **2** terminating at one end in a cathode **3** and at the other end in an extended anode **4**. Such an acceleration tube may be adapted to accelerate various types of charged particles, such as positive ions, negative ions or electrons, and merely by way of example the acceleration tube shown in Fig. 1 in an X-ray tube wherein electrons emitted at the cathode **3** are accelerated onto a gold target **5** for the production of X-rays. The tube is assembled in a vacuum-tight manner and is then evacuated through a copper tube **6** in the cathode **3** of the acceleration tube by a mechanical pump (not shown). For example, the tube may be pumped down in this manner for 3 days. The tube is then sealed off by pinching the copper tube **6** and **7** so as to form a cold-welded seal. The tube is then evacuated to a high vacuum by means of the getter ion pump which has been made integral with the acceleration tube in accordance with the invention and which will now be described in detail.

The getter ion pump comprises in combination an ionization gauge **8** and a getter chamber **9**, both of which form part of the extended anode **4** and which are therefore at ground potential except as noted hereinafter. The ionization gauge **8** operates on well-known principles whereby electrons are accelerated towards an electrode, but are hindered from reaching said electrode by the small dimensions of the electrode and by the deflecting action of a magnetic field. In the drawing, the electrode toward which the electrons are accelerated comprises a filamentary ring **10** which is supported by four short rods **11** of .030-inch stainless steel wire attached to an apertured electrode disk **12**. This filamentary ring **10** is supported in the magnetic field which exists between two ring magnets **13**. Some mild steel pieces **14** provide a path for the return flux and shield the charged particles being accelerated by the acceleration tube from the magnetic field. The magnets **13** are at ground potential and a positive potential of 2800 volts is applied to the filamentary ring **10** by a suitable power supply **15**. Electrons between the ring magnets **13**, whether produced by field emission from the surface of the magnets **13** or by ionization due to cosmic rays or otherwise, are accelerated towards the filamentary ring **10**; but the magnetic field, which may be of the order of 10^3 gausses, causing the electrons to travel in helical paths so that they do not strike the filamentary ring **10** until after they have traveled great distances. As a result, the device acts as an ionization gauge. That is to say, the device ionizes the gas in its vicinity, and the resultant current between the magnets **13** and the filamentary ring **10** is a measure of the gas pressure within the acceleration tube and may be read on the meter **16**.

Below the ionization gauge **8** is provided a grounded getter chamber **9**. Pieces of barium **17** are placed in the bottom of the chamber **9**, and the top is enclosed by an aluminum plate **18** which is provided with a series of apertures **19** and to which is attached one or more baffles **20**. Each baffle **20** may comprise, for example, a 50-mesh stainless steel screen which is spot welded in tubular form. The upper wall **21** of the chamber **9** is surrounded by a thick tube **22** of mild steel which is permanently welded to the chamber **9**. The lower wall **23** of the chamber **9** is thinner than the upper wall **21** and the mild steel ring **24** which surrounds it is removed during evaporation of the getter. The purpose of the mild steel members **22** and **24** is to shield the charged particles being accelerated by the acceleration tube from external magnetic fields such as those produced by the drive motor of an electrostatic accelerator in which the tube might be placed.

Referring now to Fig. 3, during evaporation of the barium getter, the lower wall **23** of the chamber **9** is surrounded by an oven **25**, while the upper wall **21** of the chamber **9** is surrounded by a water-cooled jacket **26**. The barium **17** is heated to evaporation temperatures, such as 820° centigrade, in the oven and the barium vapor is condensed principally on the inner surface of the upper wall **21** of the chamber **9** but also on the baffles **20**. Surfaces on which the barium getter is deposited are shielded from later being struck by the beam of charged particles by providing cylindrical tubular members **27** through which said beam travels. It will now be seen that the apertures **19** in the top plate **18** are necessary in order that any gas within the acceleration tube may travel therethrough and be trapped by the getter.

As stated hereinbefore, an important feature of the

invention is the provision of heat for the evaporation of the getter from a heat source outside the acceleration tube to be evacuated. In accordance with this aspect of the invention, it is only necessary that the actual heat source be external to the evacuated region and not exposed thereto. Thus, for example, the external heat source of the invention may comprise a hollow metal tube which is introduced into the evacuated region through a vacuum-tight seal and within which a heating element is provided. The heat source is thus external to the evacuated region and is separated therefrom by the hollow metal tube, which is grounded and vacuum tight.

In our work we have employed an active metal getter, preferably barium, in combination with ionization to pump on the complex gaseous ingredients of high voltage acceleration tubes. We have preferentially used barium as the active metal getter and have included relatively large amounts of barium in these pumps in order to give them extended pumping times ranging into years. Even a small pump of this type for example is commonly given between 10 and 100 grams of barium, and pumps are now being designed which contemplate an initial loading of pounds of barium.

In one embodiment of the invention the pump is of the intermittent type. The barium is evaporated onto a cold surface which subsequently absorbs over an extended period of time the gas molecules which come in contact with it. On a typical acceleration tube of the megavolt class, a single evaporation, for example, may subsequently maintain a high voltage-insulating vacuum within the tube for a period ranging from 1 month to 1 year. This pump, however, is capable of repeated evaporation cycles whenever further fresh gettering surfaces become necessary.

The invention also comprehends a container loaded with getter-coated surfaces and provided with a source of ionization. Such containers could be bolted on any system requiring the maintenance of a high vacuum and then connected to it by opening a valve. This would in effect be a getter-ionization pump in which the evaporation has been accomplished in advance.

Having thus described the method of the invention, together with a preferred embodiment of apparatus for carrying out the method, it is to 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. In combination with a sealed-off system containing electrodes at high potential, means for exciting and ionizing the residual gas within said sealed-off system, a metallic getter within said sealed-off system, and means for shielding said excitation-ionization means and said getter from the electric fields associated with said high potential.

2. In combination with a sealed-off system containing electrodes at high potential, means for exciting and ionizing the residual gas within said seal-off system, a metallic getter within said sealed-off system, and a heat source external to said sealed-off system and adapted to evaporate said getter.

3. In combination with a sealed-off system containing electrodes at high potential, means for exciting and ionizing the residual gas within said sealed-off system, an amount of barium within said sealed-off system at least of the order of 10 grams, and a heat source external to said sealed-off system and adapted to evaporate said barium periodically.

4. In combination with apparatus for the acceleration of charged particles including a tube traversed by a stream of charged particles, the construction of said tube being such that the rate of evolution of gas therein may exceed 10^{-7} millimeter-liters per second, a getter-ionization pump integral with said tube.

5. In combination with apparatus for the acceleration of charged particles including a tube traversed by a stream of charged particles, the construction of said tube being such that the rate of evolution of gas therein may exceed 10^{-7} millimeter-liters per second, a getter-ionization pump within said tube and concentric with the path of said stream of accelerated charged particles.

6. In combination with apparatus for the acceleration of charged particles including a tube traversed by a stream of charged particles, the construction of said tube being such that the rate of evolution of gas therein may exceed 10^{-7} millimeter-liters per second, means within said tube for ionizing the residual gas in said tube, a getter within said tube having an extensive surface area, and means for shielding said ionization means and said getter from the beam of charged particles accelerated by said tube during operation thereof.

7. Apparatus in accordance with claim 6 wherein said getter comprises barium.

8. Apparatus in accordance with claim 7 wherein said getter comprises barium in an amount at least of the order of 10 grams.

9. In combination with a multiple-electrode acceleration tube comprising a series of alternating insulating rings and apertured electrodes cemented by a synthetic resin and closed off at one end by an end piece and at the other end by a tube extension, a getter-ion pump integral with said acceleration tube.

10. In combination with a multiple-electrode acceleration tube comprising a series of alternating insulating rings and apertured electrodes closed off at one end by an end piece and at the other end by a grounded tube extension, a getter-ion pump integral within said grounded tube extension.

11. A multiple-electrode acceleration tube comprising in combination a series of alternating insulating rings and apertured electrodes cemented by a synthetic resin and closed off at one end by a cathode and at the other end by an anode extension, a pair of axially aligned ring magnets supported within said anode extension, a filamentary ring supported between said ring magnets in axial alignment therewith, means for imparting a positive voltage to said filamentary ring with respect to said ring magnets, a getter within said anode extension having an extensive surface area, and at least one tubular shield supported axially within said anode extension so as to shield said ionization means and said getter from the beam of electrons accelerated by said tube during operation thereof.

12. A method of assembling a high-vacuum sealed-off system without outgassing the same, which method comprises the following steps: assembling a system and hermetically sealing the same with the exception of an aperture for pumping, said system having therein an amount of metallic getter at least of the order of 10 grams and ionization means, said assembly being performed without outgassing so that the rate of evolution of gas within said system may exceed 10^{-7} millimeter-liters per second, evacuating said system to fore-vacuum pressure through said aperture, hermetically sealing said aperture so as to seal off said system, evaporating said metallic getter by means of a heat source external to said sealed-off system, and cooling an extensive surface area within said sealed-off system so that the evaporated getter condenses thereon.

13. A method of assembling an acceleration tube which method comprises the following steps: cementing together a multiplicity of alternating insulating rings and apertured electrodes; sealing to the end thereof an end-piece having a small tube therethrough and a tube extension, respectively, said tube extension having therein a large amount of barium and ionization means; evacuating said accelera-

tion tube to fore-vacuum pressure through said small tube in said end-piece; pinching off said small tube so as to seal off said acceleration tube; evaporating said barium by means of a heat source external to said acceleration tube; and cooling an extensive surface area within said tube extension so that the evaporated barium condenses thereon.

14. A method in accordance with claim 13 wherein the amount of barium evaporated is at least of the order of 10 grams.

15. In combination with a sealed-off system for the acceleration of charged particles whose envelope includes materials which do not permit the application of temperatures substantially above 200° C. for outgassing purposes, a getter-ionization pump integral with said system.

References Cited in the file of this patent

UNITED STATES PATENTS

2,332,428	Atlee et al.	Oct. 19, 1943
2,540,647	Bienfait	Feb. 6, 1951
2,636,664	Hertzler	Apr. 28, 1953
2,640,948	Burrill	June 2, 1953
2,656,489	Ford	Oct. 20, 1953
2,796,555	Connor	June 18, 1957
2,838,708	Yoder	June 10, 1958

OTHER REFERENCES

"Evapor-Ion Pump," by H. G. Herd, R. H. Davis, A. S. Divatis and D. Saxon, Physical Review, 2nd series, vol. 89, No. 4, page 897, February 13, 1953.