Dec. 5, 1939. J. G. TRUMP 2,182,185

HIGH VOLTAGE IONIC DISCHARGE DEVICE

Filed June 24, 1938

Fig. 1.

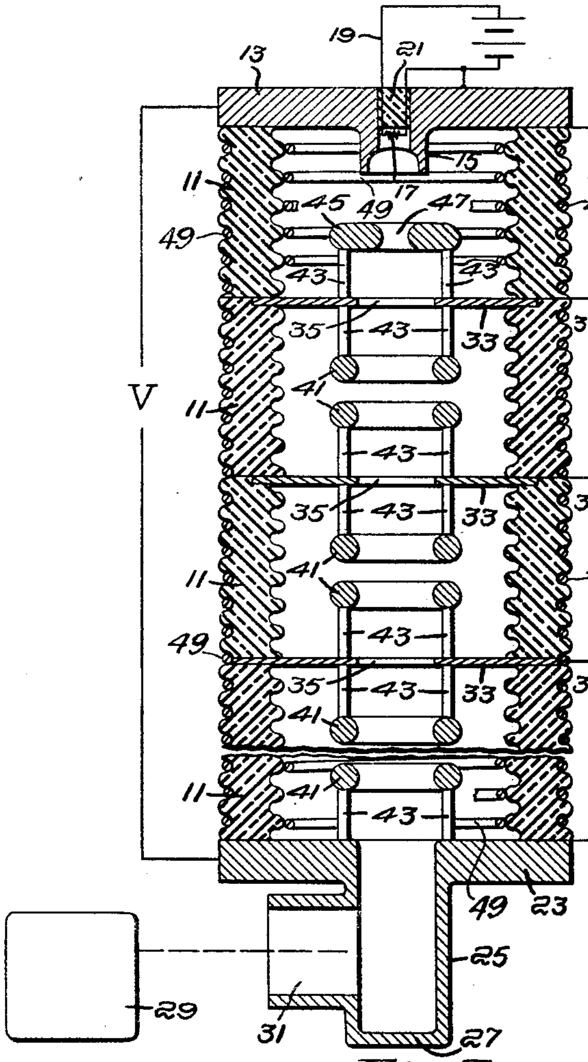


Fig. 2.

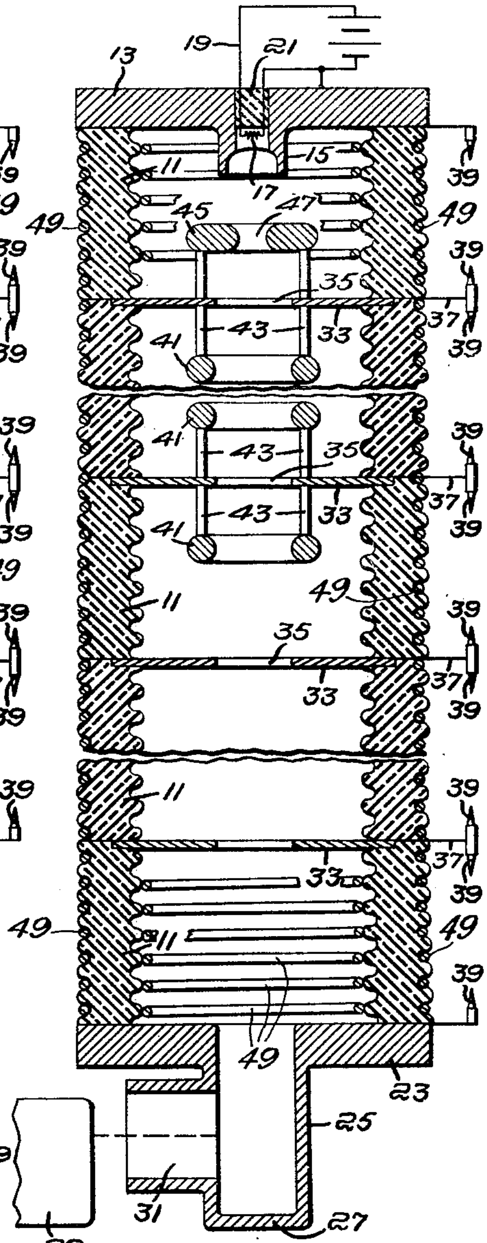
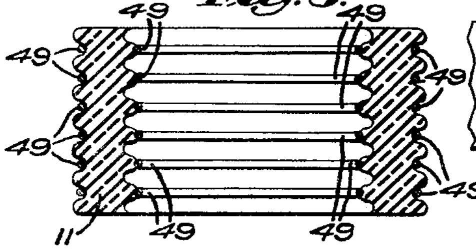


Fig. 3.



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2,182,185

HIGH VOLTAGE IONIC DISCHARGE DEVICE

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8 Claims. (Cl. 250—27.5)

This invention relates to high-voltage ionic discharge devices of the multiple acceleration type in which a beam of charged particles is caused to travel at accelerated stages across a plurality of gaps under progressively higher potentials within a highly evacuated tube or other container.

One object of the invention is to provide a practical, efficient discharge device for the acceleration of charged particles employing the multiple acceleration principle, which device is of relatively simple construction, capable of withstanding very high voltages and of producing and accelerating a beam of charged particles under conditions which maintain a well defined focusing effect and an adequate shielding effect on the beam.

Another object is the provision of a high-energy discharge tube of this character in which the insulation strength along the envelope, both within the evacuated container and without, is maintained at a controlled maximum value, thus permitting the attainment of extremely high-energy charged particles in a compact and rugged apparatus.

Another object is the provision of a high-voltage discharge tube of this character susceptible of a high pumping speed between the ends of the tube, that is to say, a relatively high rate of removal for the evolving gases. This facilitates the extension of acceleration tubes to higher voltages, or with the same voltage to secure the same effect with smaller apparatus.

One common disadvantage of tubes heretofore utilized for this purpose, where high potentials are employed (as, for example, of the order of a million volts) and where the discharge path is necessarily elongated, is the requirement of continuous pumping for the removal of gases evolved in the use of the tube to maintain the required vacuum and the low pumping speed which the construction of such tubes enforces.

The consideration of pumping speed is of particular importance when the particles to be accelerated are positive ions drawn from a low pressure discharge at the anode end of the tube. In this case, gas at low pressure is continually diffusing into the highly evacuated acceleration tube from the orifice from which the ions are drawn. High pumping speed must therefore be maintained to draw off the evolving gas with sufficient rapidity to preserve the highly evacuated condition required for the insulation of high voltages and the full effectiveness of the tube. Even with X-ray tubes, in which the charged particles are electrons emitted from a hot filament, there may be need for a relatively high pumping speed, since the filament, particularly when setting the tube in operation, is itself a source of gas which must be rapidly withdrawn to prevent local breakdowns. Similarly, the entire target, upon which the accelerated electrons or ions finally impinge, becomes heated in the process and therefore a source of gas which must be withdrawn.

These and other objects of the invention will be best understood by the following description when taken with the accompanying illustration showing two specific embodiments thereof, while its scope will be more particularly pointed out in the appended claims.

In the drawing:

Figure 1 shows in sectional elevation, partly broken away, a discharge device embodying one form of the invention;

Fig. 2 is a similar section showing a modified form of the invention; and

Fig. 3 is a detail of the corrugated cylinder utilized in Figs. 1 and 2 and showing a portion of the porcelain cylindrical envelope equipped with spaced, equi-potential conductive rings.

Referring to the drawing, and more particularly to Fig. 1, the discharge device comprises an evacuated tubular container or envelope, herein consisting of a cylindrical body 11 of porcelain or like insulating material, preferably having corrugated walls both on the inside and outside. This may consist of a continuous tube or cylinder, or, as indicated in the drawing, it may be formed from a plurality of sectional tubes hermetically sealed together.

One end of the tube 11 is hermetically sealed by a metal conductive plate 13 having the inwardly projecting part 15 coinciding with the axis of the tube and constituting an electrode which is provided with a somewhat concaved mouth within which is located the cathode filament 17. The latter has electrical connection to the electrode 15 and is adapted to be brought to and maintained at incandescence by the heating circuit 19 passing through the plate but insulated therefrom by the plug 21.

The opposite end of the tube 11 is hermetically sealed by the metal conductive plate 23, terminating in a tubular extension 25 coaxial with the tube and closed by the plate 27 which constitutes the anode or opposite one of the two main electrodes. A high potential difference (as, for example, of the order of 1,000,000 volts) is impressed on the end plates 13 and 23 by any suitable means, not herein shown but diagrammatically indicated by a circuit and symbol V. If continuous pumping means is to be employed for the removal of the evolved gases, there may be utilized any usual form of high speed vacuum pump, which is here conventionally indicated at 29 and connected to the interior of the cylinder through the connection 31 opening into the tubular extension 25.

Within the tube there are provided a plurality of transversely arranged, relatively thin plates or diaphragms 33 of conductive metal, such as steel, having each a central aperture 35 coaxial with the cylinder and preferably equally spaced lengthwise the cylinder, defining a plurality of successive sections or compartments for the interior of the cylinder. These diaphragms may be maintained in fixed position, as indicated in the drawing, by having each its peripheral edge set in a groove formed on the inner edge of one of the adjoining sections of the cylinder, or by having its edge sprung into position in a corrugation on the inner walls of the cylinder, or in a groove especially formed for that purpose.

To provide for the acceleration by stages, each representing but a part of the total voltage V, the successive diaphragms are connected each to a lead wire 37 passing through the porcelain body of the cylinder to the outside thereof, these successive diaphragms being thereby connected to successive members of a series of pairs of opposed, spaced corona points 39. One corona point of each pair which is connected to one diaphragm is spaced by a gap from the corona point of the next preceding diaphragm, while the other corona point of the same pair occupies a similar position to a corona point of the next succeeding diaphragm. The opposite extreme members of such series of corona points are connected respectively to the plates 13 and 23 and are positioned in operative relation to the corona points of the next adjacent diaphragms. This maintains successive plates 33 at potential differences, each a substantially equal part of the total potential V. Any suitable means for accomplishing the same purpose, however, may be employed, such as interposing resistors between the lead wires 37, or connecting such wires to successive portions of the transformer secondary.

An alternative construction is to allow the transversely arranged diaphragms to separate the insulating cylinder into sections by extending to the outside thereof, as indicated in the arrangement of the lowermost diaphragm 33 in Fig. 1. This eliminates the necessity of the lead wire 37 passing through the wall 11, the spaced corona points 39 being attached directly to extensions of these diaphragms. This construction involves the necessity of a vacuum-tight seal between the faces of the diaphragm and the abutting insulating cylinders. This seal is accomplished by means of compressed gaskets of suitable low-vapor-pressure material.

The number of successive stages of potential difference, as determined by the number of diaphragms employed, will depend on the total voltage utilized. By way of illustration, if a potential difference of 1,000,000 volts is to be utilized, nineteen diaphragms might be used so as to bring the potential difference in each section of the tube to the order of a magnitude of 50,000 volts.

In each of the sections of the cylinder between the diaphragms 33 and transversely the section, there is also provided a pair of circular, apertured, ring-like members or annuli 41 of conductive metal, spaced from each other by a gap, with their central apertures in alignment and coaxial with the cylinder and with the apertures of the diaphragms. These ring-like members are of such an outside diameter as to leave a substantial clearance between their outer edges and the inner walls of the cylinder. Each annulus 41 is supported by its adjacent diaphragm 33 through a plurality of pins or rods 43 (there may be employed, for example, three or four equally spaced rods) preferably of conductive metal, these serving to connect the ring both electrically and mechanically to the next adjacent diaphragm. Each diaphragm is equipped with two such ring-like members, one in the section at one side of the diaphragm and opposed to but spaced from a similar member attached to the preceding diaphragm and another in the section at the opposite side of the first diaphragm and opposed to but spaced from a similar ring attached to the succeeding diaphragm.

The section of the cylinder adjoining the anode is provided with a similar ring 41, which is electrically connected to and supported by the plate 23 and operatively related to the ring 41 carried by the next preceding diaphragm. The diaphragm next adjacent the cathode filament is provided with a ring 45 spaced from the electrode 15. The ring 45 is generally similar to the rings 41 but, if desired, may be provided with a part projecting toward the aperture of the diaphragm to which it is connected. It is provided with an axial passage 47, somewhat more restricted than the central aperture in the remaining rings. This is for the purpose of defining a narrow beam of charged particles.

Since one ring of any one spaced pair is electrically connected to a diaphragm maintained at one potential value and the other opposed ring is connected to a diaphragm maintained at the next potential value of the progressive series, successive pairs of spaced rings provide a progressive series of inter-electrode gaps, across each of which the acceleration of the charged particles for that section of the cylinder takes place under the potential difference there maintained, and in which, through the action of the rings, the main focusing effect on the charged particles is produced.

Although the cross section of any one portion of the rings 41 is herein shown as circular, other cross sections may be employed, as, for example, one approximately rectilinear. Preferably, however, a relation between the rings is preserved such that the intervening gap is not greater than the diameter of the apertures in the rings themselves.

In the operation of the tube the function of the thin, conductive diaphragms is to electrically separate the insulating cylinder lengthwise into discrete intervals and to apportion the total voltage between these insulating intervals. Thus within the cylinders, by reason of these diaphragms, the problem of insulating an extremely high voltage of the order of a million has been reduced to the problem of insulating a relatively low voltage in each of a number of gaps. Only through the aperture of these diaphragms can the total voltage be seen from one main electrode to another,—a situation which is necessary for the passage of the charged particle beam and which is not serious from the voltage insulation standpoint since these apertures are relatively well shielded. This arrangement alone, however, will not readily permit a well-focused beam to traverse from one main electrode to the other, since a definite focusing action is required to maintain the charged particles in a compact beam. This function is accomplished by the successive series of spaced rings which provide a progressive series of inter-electrode gaps between each of which exists a field distribution of such configuration as to impel the charged particles toward the axial center of the tube. While these successive series of spaced rings thus serve to redirect such charged particles as have strayed slightly from the true axis of the tube, and at the same time, because of the difference of potential across the gap, to increase the energy of the charged particles by an amount equal to the gap voltage, they require the cooperative use of the diaphragms to shield each section of the tube from the others.

In the event that continuous pumping is employed for the removal of the evolved gases, the pumping speed in the described construction is relatively high through the axial region where the ion beam is constrained to pass, and higher than in those prior constructions where the beam is required to travel axially through tubes provided for their shielding and focusing effect. The rings 41 offer substantially no interference to the pumping speed, and the latter is limited mainly by the size of the orifices in the diaphragms 33, the open spacing between any ring and its adjoining diaphragm permitting the diffusion of gas throughout any one section as well as through the diaphragm opening. With the same diameter of orifice, for example, the pumping speed through a tube having a length six times the diameter of its orifice would be about one-fifth of that of a diaphragm having an aperture of the same diameter.

The pumping speed through the diaphragms in the proposed construction may be considerably increased by providing, in addition to the central aperture, a number of holes or perforations small in relation to the central aperture and preferably of a diameter of the order of the diaphragm thickness. By providing a suitable number of such perforations, the pumping speed may be increased, for example, several times that otherwise obtainable, all without substantial impairment of the shielding effect of the diaphragms.

In the embodiment of the invention shown in Fig. 1, substantially similar sections equipped each with spaced rings forming inter-electrode gaps are provided for the entire length of the tube from one main electrode to the other. In actual operation the main focusing effect on the beam is produced during the early acceleration stages. When the charged particles have acquired a relatively high energy, the focusing action which can be exerted on a beam becomes relatively slight. In high voltage discharge devices, where the particles in approaching the target end of the tube have acquired high energy, the ring-like members which are provided in sections near the ion source end of the tube may be omitted near the target end thereof, and the function of acceleration for such section or sections near the target end of the tube left to the diaphragms with their central apertures. Such modified construction is indicated in Fig. 2, where the first two or more sections of the cylinder near the cathode end of the tube are equipped with both diaphragms and rings, as previously described, while the final two or more sections near the anode end of the tube are provided with the diaphragms only, the latter, however, being connected, as before, to their respective corona points to maintain the succession of steps of potential differences.

The construction of the corrugated cylinder is illustrated more in detail in Fig. 3, where each corrugation is preferably provided with a ring or thin coating 49 of conductive material such as copper or steel, so that the walls thereof are provided with a series of separate, spaced, conductive, equi-potential rings. Preferably these rings, which are indicated in Figs. 1 and 2, are applied to corrugations both on the inside and outside walls of the cylinder, and may be applied to each corrugation at either its crest or trough, or both at its crest and its trough. In Fig. 3 there is shown a conductive ring 49 for each outside corrugation at its trough and for each inside corrugation at its crest.

It has been observed in laboratory tests of solid insulation in vacuum that the breakdown proceeds in the form of gliding discharges along the insulator surface from one electrode toward the other. Experiments have also shown that by corrugating the insulating surface between two electrodes at a difference of potential, the voltage at which such gliding discharges arise is considerably increased. Experiments further have shown that by providing definite equi-potential planes formed by conductive rings around the tips of such corrugations or in the depths of such corrugations, or both, a far more uniform potential distribution exists along the surface of the insulator, in consequence of which the voltage at which a failure takes place along the insulating surface is still further increased. Therefore in the high-voltage acceleration tube it is desirable that the cylinder be corrugated and, further, that on each corrugation a definite potential level be maintained and a uniform distribution of potential exist from corrugation to corrugation.

This construction, while intended in part to increase the voltage strength of the insulating cylinder lengthwise the cylinder, has also the beneficial effect of controlling and preventing the formation of intense bound charges on the insulator surface which may result in the puncture of the cylinder wall.

Additionally, this use of equi-potential rings has the important effect of eliminating much of the unsteadiness of the ion beam position caused by fluctuating, unsymmetrically disposed, bound charges on the insulator surface. This is due to the fact that the equi-potential rings are symmetrical to the beam axis and therefore have no beam displacing tendency.

By means of this construction, an acceleration tube has been developed which is exceedingly difficult either to flash over inside or outside and lengthwise the tube, or to puncture through the wall of the tube, and at the same time permits much more effective and steady focusing of the ion beam,—all difficulties which are among the chief obstacles in the development of the art.

While for the purposes of illustration the invention is shown as embodied in specific forms of apparatus, extensive changes and deviations may be made in the construction, form and relation of the parts herein shown, without departing from the principles of the invention.

I claim:

1. A high voltage electrical discharge device for the multiple acceleration of charged particles, comprising a thick-walled, highly evacuated, insulating container having a pair of main electrodes

between which a beam of charged particles is adapted to pass, means to establish lengthwise on the interior walls of the container a series of equi-potential surfaces transversely of the container and means separating said envelope interiorly into a plurality of successive communicating sections comprising a plurality of orificed diaphragms for shielding said surfaces from direct impact by the beam of accelerated particles, and maintaining a limited, controlled difference of potential in each section.

2. A high voltage electrical discharge device for the multiple acceleration of charged particles, comprising a thick-walled, highly evacuated, insulating container having a pair of main electrodes between which a beam of charged particles is adapted to pass, means to establish lengthwise on the interior walls of the container equipotential surfaces transversely of the container and symmetrically arranged with relation to the beam axis, the same comprising spaced, conductive rings applied to the surface of the container and means separating said envelope interiorly into a plurality of successive communicating sections comprising a plurality of orificed diaphragms for shielding said surfaces from direct impact by the beam of accelerated particles, and maintaining a limited, controlled difference of potential in each section.

3. A high voltage electrical discharge device for the multiple acceleration of charged particles, comprising a thick-walled, highly evacuated, insulating container having a pair of main electrodes between which a beam of charged particles is adapted to pass, the walls of said container being both internally and externally corrugated transversely to the axial length thereof, means to establish lengthwise the container a series of equi-potential surfaces transversely of the container and symmetrically arranged with relation to the beam axis, the same comprising spaced, conductive rings applied to the corrugated walls of the container and means separating said envelope interiorly into a plurality of successive communicating sections comprising a plurality of orificed diaphragms for shielding said surfaces from direct impact by the beam of accelerated particles, and maintaining a limited, controlled difference of potential in each section.

4. An electrical discharge device for the multiple acceleration of charged particles, comprising an elongated, evacuated envelope of insulating material provided with main electrodes, a plurality of conductive diaphragms defining successive sections lengthwise of the interior of said envelope and between said electrodes, said successive diaphragms having orifices in axial alignment lengthwise of the envelope and in the path of the charged particles, means for accelerating and focusing a beam of charged particles along the interior of said envelope, the same comprising a pair of separated ring-like members of conductive material in a section of said envelope, each member being supported by but openly spaced from and electrically connected to its adjacent diaphragm, and means for dividing the potential difference of the main electrodes between successive diaphragms.

5. An electrical discharge device for the multiple acceleration of charged particles, comprising an elongated, evacuated envelope of insulating material provided with main electrodes, a plurality of conductive diaphragms defining successive sections lengthwise of the interior of said envelope and between said electrodes, said successive diaphragms having orifices in axial alignment lengthwise of the envelope and in the path of the charged particles, means for accelerating and focusing a beam of charged particles, the same comprising a pair of separated ring-like members of conductive material in a section of said envelope, each member being supported by but openly spaced from and electrically connected to its adjacent diaphragm, said ring-like members being applied only to certain of said diaphragms adjacent the source of charged particles, and means for dividing the potential difference of the main electrodes between successive diaphragms.

6. A high voltage electrical discharge device for the multiple acceleration of charged particles, comprising an elongated, evacuated, insulated envelope provided with main electrodes, spaced diaphragms of conductive material provided each with a central aperture and extending across the interior of the envelope between said main electrodes to establish successive communicating sections therein, successive diaphragms being adapted to divide between them the potential difference of the main electrodes, and means for establishing an inter-electrode acceleration and beam focusing gap between the diaphragms of a section comprising a pair of ring-like members in spaced relation, one supported by but openly spaced from one diaphragm and the other supported by but openly spaced from the next adjacent diaphragm, said members being in coaxial relation to each other and to the apertures of the diaphragms.

7. An electrical discharge device for the multiple acceleration of charged particles, comprising an elongated, evacuated envelope of insulating material provided with opposite electrodes, means for electrically separating said envelope lengthwise between said electrodes into sections communicating with one another by a relatively restricted central passage, and having inter-electrode means in one of said sections for accelerating and focusing a beam of charged particles, the same comprising spaced ring-like electrodes openly spaced from said separating means, coaxial with said passage and adapted to be maintained at different potentials.

8. A discharge device for the acceleration of charged particles, comprising an elongated, evacuated envelope of insulating material, two main electrodes between which a beam of charged particles is to pass, said envelope being spaced lengthwise into communicating sections between said electrodes by a series of disks each with an axial aperture, and means for maintaining an electric field for progressively accelerating charged particles to high energies and refocusing said beam at a region along its length, said means consisting at said region of a pair of separated ring-like electrodes adapted to be maintained at different potentials, said pair of ring-like electrodes being axially related, each within one of said communicating sections, and providing an open diffusion space about the same and between the same and the adjoining disk.

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