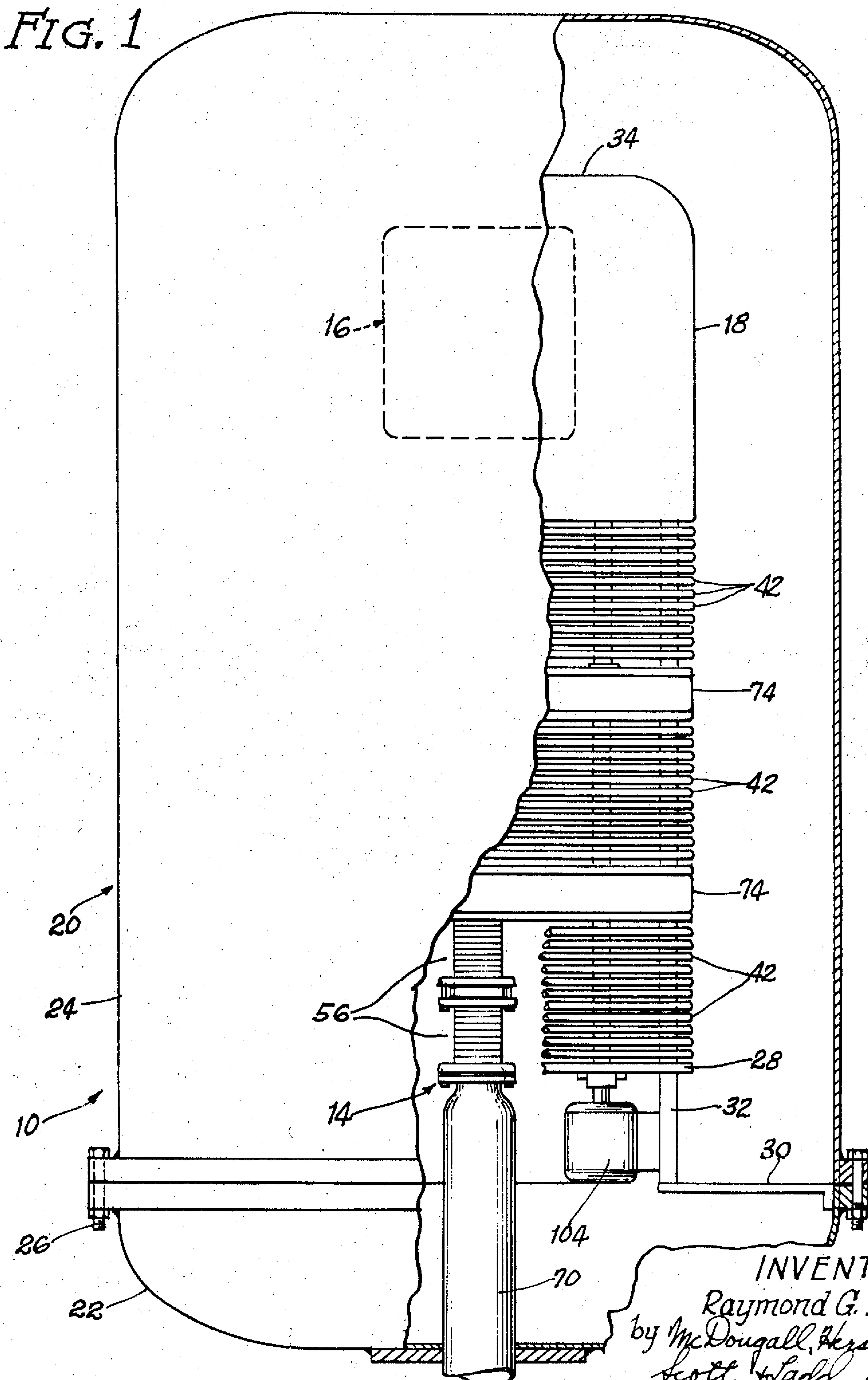
Oct. 14, 1969 R. G. HERB 3,473,064

HIGH VOLTAGE ACCELERATOR AND ACCELERATING TUBE THEREFOR

Filed Aug. 2, 1967 3 Sheets-Sheet 1

FIG. 1



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HIGH VOLTAGE ACCELERATOR AND ACCELERATING TUBE THEREFOR

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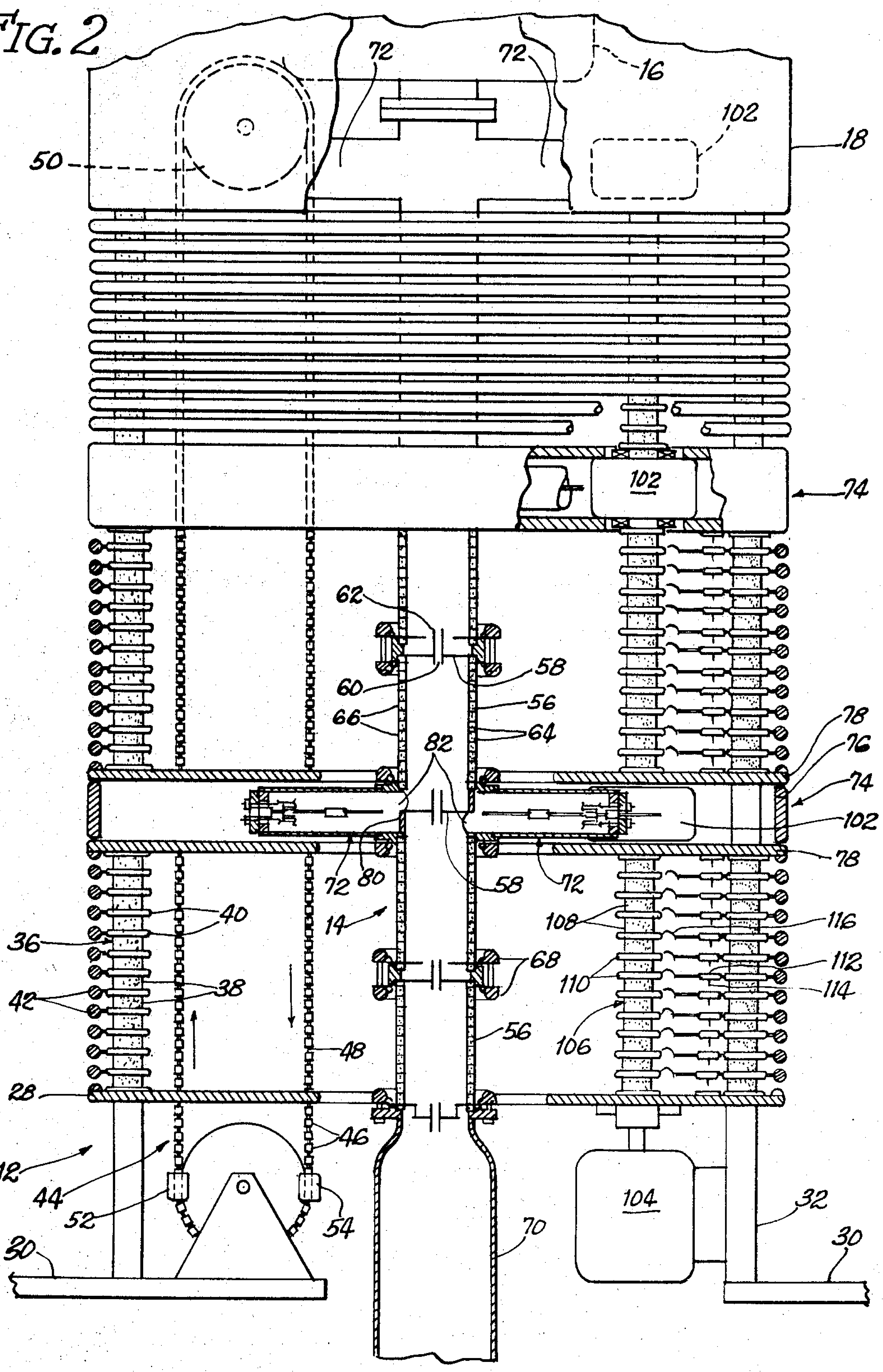
FIG. 2



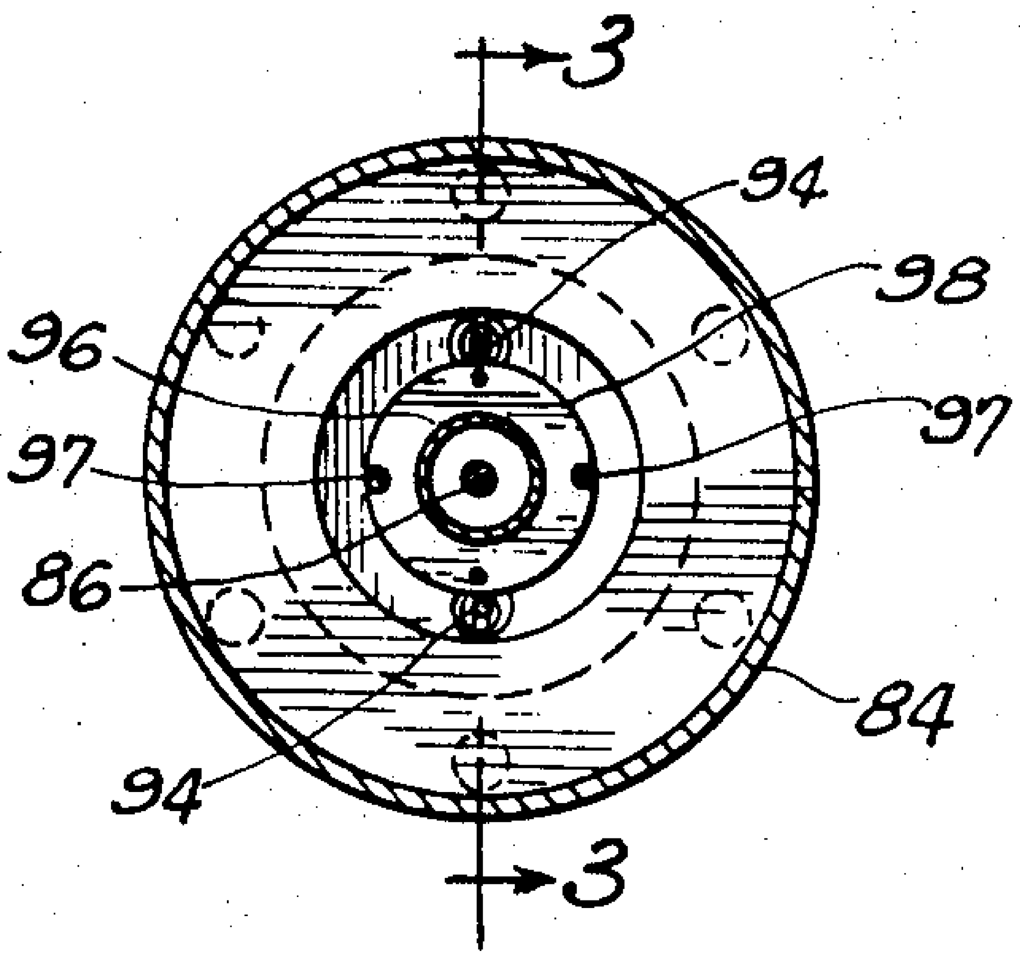


FIG. 4

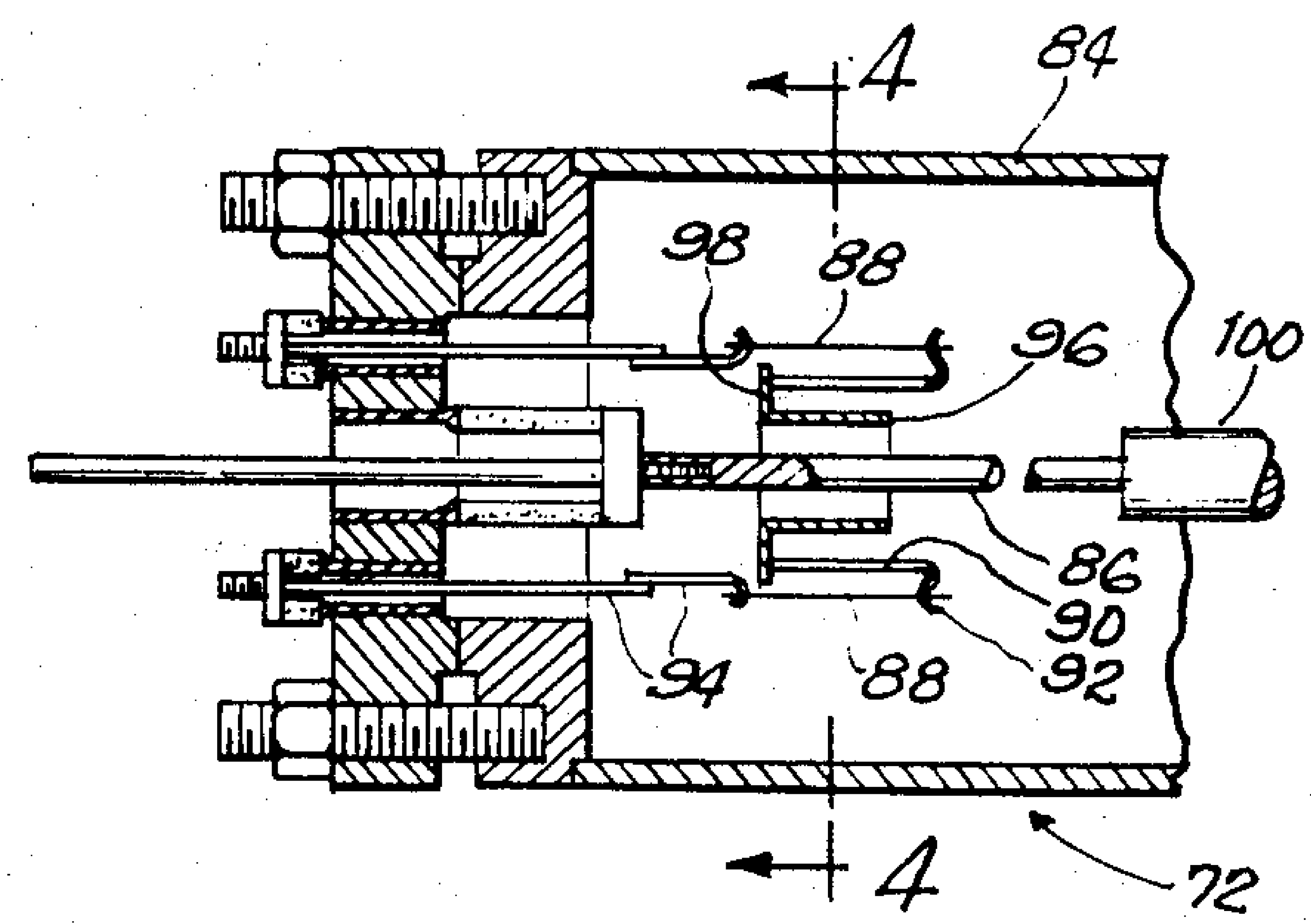


FIG. 3

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HIGH VOLTAGE ACCELERATOR AND ACCELERATING TUBE THEREFOR

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Int. Cl. H01j 7/16
U.S. Cl. 313—7 15 Claims

ABSTRACT OF THE DISCLOSURE

A high voltage accelerator, comprising a grounded supporting member, a high voltage electrode, a plurality of intermediate electrodes, insulators connected therebetween, means for charging the high voltage electrode to a high voltage, an accelerating tube connected between said high voltage electrode and said grounded supporting member, said tube extending through said intermediate electrodes, said tube comprising a plurality of insulating tubular sections connected together end to end, a plurality of isolating diaphragms disposed between said sections, each diaphragm having an aperture therein for the passage of the charged particles to be accelerated in said tube, two of said insulating sections being connected between each pair of adjacent intermediate electrodes, and a plurality of evacuating devices connected separately to said sections for separately evacuating said sections, two of said evacuating devices being mounted on each of said intermediate electrodes and being connected to the sections on the opposite sides of the adjacent diaphragm, another of said evacuating devices being mounted on the high voltage electrode, each of said evacuating devices preferably comprising a vacuum pump having ionizing means and gettering means.

This invention relates to high voltage accelerators and accelerating tubes for such accelerators.

Generally, a high voltage accelerator comprises a high voltage generator, an accelerating tube adapted to utilize the high voltage developed by the generator, and an ion source for producing the charged particles which travel within the tube and are accelerated by the high voltage. The high voltage generator generally comprises a high voltage electrode, insulators for supporting the electrode on a grounded base, and means for charging the high voltage electrode to a high voltage.

It is the usual practice to mount the high voltage accelerator within a tank which is filled with a suitable gas at high pressure, to provide an insulating atmosphere which prevents high voltage flashovers between the high voltage electrode and the grounded base. Sulfur hexafluoride is commonly used as the insulating high pressure gas, because of its high dielectric strength. However, other suitable gases may also be employed.

The use of the high pressure dielectric gas has virtually eliminated flashovers in the atmosphere around the accelerator. However, flashovers have still been a problem within the accelerating tube. Of course, a high vacuum is established and maintained within the accelerating tube, so that the charged particles may be accelerated along the tube, with a minimum chance that the charged particles will collide with residual gas molecules. It has been found that flashovers occur much more readily in the vacuum within the accelerating tube, than in the high pressure atmosphere around the outside of the tube.

Moreover, it has been found that short accelerating tubes are proportionately more efficient than long tubes in withstanding high voltages. Thus, for example, if a tube of a certain length will withstand 1,000,000 volts, a similar tube twice as long will not normally withstand 2,000,000

volts. Thus, it has become evident that merely increasing the length of the accelerating tube is not an adequate solution to the problem of providing a tube which will withstand an extremely high voltage. This long tube effect, whereby long accelerating tubes are proportionately less efficient than short tubes, makes it difficult to produce a high voltage accelerator which will operate at many millions of volts. The tendency is for the machine to become excessively large and expensive.

The principal object of the present invention is to deal with this problem, and to provide a high voltage accelerator having a reasonably short accelerating tube which will withstand several million volts without flashovers.

The present invention contemplates a high voltage accelerator comprising an accelerating tube which is subdivided into a plurality of insulating sections, arranged end to end. Isolating diaphragms are provided between the sections. The diaphragms are preferably made of conductive material. Each diaphragm is formed with an aperture to provide for the passage of the charged particles. These apertures provide the only communication between the successive sections of the accelerating tube. The apertures are of a size which is small, when compared with the inside diameter of the accelerating tube. A plurality of evacuating devices are connected separately to some and preferably all of the sections. Thus, it is preferred to provide each section with a separate evacuating device. The subdivision of the accelerating tube generally prevents the propagation of any discharge, originating somewhere in the accelerating tube, which might otherwise cause a total flashover. The separate evacuating devices insure that a high vacuum will be maintained in all of the sections, even though gas may be evolved locally in the accelerating tube due to some minor or insipient discharge. The evacuating devices are preferably in the form of vacuum pumps, but may also be in the form of passive gas absorbers, involving the use of activated getter materials. Vacuum pumps of various types may be employed. However, it is preferred to employ ion-getter pumps having both ionizing means, for ionizing the residual gases, and gettering means, for absorbing the gas ions and molecules. The high voltage accelerator preferably comprises a high voltage electrode and one or more intermediate electrodes interspersed between the high voltage electrode and the grounded base. Two sections of the accelerating tube are preferably connected between each adjacent pair of electrodes, so that one of the diaphragms is at each electrode. Two separate evacuating devices are preferably mounted on each intermediate electrode, and are connected separately to the sections on opposite sides of the adjacent diaphragm.

Further objects and advantages of the present invention will appear from the following description, taken with the accompanying drawings, in which:

FIG. 1 is an elevational view, partly in longitudinal section, showing a high voltage accelerator to be described as an illustrative embodiment of the present invention.

FIG. 2 is a fragmentary longitudinal section showing the high voltage generator of the accelerating tube for the accelerator.

FIG. 3 is a fragmentary enlarged section showing one of the ion-getter vacuum pumps employed as an evacuating device for the accelerating tube, the view being taken generally along the line **3—3** of FIG. 4.

FIG. 4 is a sectional view taken generally along the line **4—4** of FIG. 3.

As already indicated, FIGS. 1 and 2 illustrate a high voltage accelerator **10** for accelerating charged particles to high energy levels. The charged particles may comprise protons, deuterons, or electrons, for example. The accelerator is capable of developing a working voltage of several million volts for accelerating the charged particles.

Generally, the accelerator **10** comprises a high voltage generator **12**, an accelerating tube **14**, and an ion source **16**. The generator **12** produces a voltage ranging up to several million volts. This voltage is employed to accelerate the charged particles in the accelerating tube **14**. The ion source **16** produces the charged particles and directs them into the accelerating tube **14** so that they will travel along the tube and be accelerated by the high voltage.

The high voltage generator **12** is preferably of the electrostatic type comprising a high voltage electrode **18** to which electrostatic charges are transported, so as to raise the voltage of the electrode. The entire high voltage generator **12** is preferably surrounded with a high pressure atmosphere comprising a gas having high dielectric strength. The use of the high pressure gas prevents flashovers between the high voltage electrode **18** and ground. Flashovers at other points are also prevented. It is preferred to employ sulfur hexafluoride as the high pressure dielectric gas, but other suitable gases may also be employed. To contain the high pressure atmosphere, the high voltage generator **12** is mounted within a tank **20**, preferably made of steel or the like. The illustrated tank **20** comprises a lower section or base **22** and a removable upper section **24** which is normally clamped to the base **22** by means of bolts **26**. When it is desired to do work upon the high voltage generator **12** or the accelerating tube **14**, the upper section **24** of the tank may be removed, after most of the dielectric gas has been withdrawn so as to reduce the pressure within the tank.

As illustrated, the high voltage generator **12** is mounted on a supporting member in the form of a plate **28** which is secured to the base **22** of the tank **20**. The supporting plate **28** is preferably made of steel or other conductive material and is grounded so as to serve as the grounded electrode of the high voltage generator. Brackets **30** may be employed to connect the plate **28** to the base **22**.

The high voltage electrode **18** is illustrated in the form of a hollow conductive cylinder which is open at its lower end but is closed at the opposite end by an upper wall **34**. Thus, the illustrated construction is single-ended, but a double-ended construction may also be employed, as disclosed in the copending application of Raymond G. Herb and James A. Ferry, Ser. No. 557,818, filed June 15, 1966. The high voltage electrode **18** is supported by a plurality of insulators in the form of columns or posts **36**. The lower ends of the insulators **36** are mounted on the grounded supporting plate **30**. The upper ends of the insulators **36** are connected to the high voltage electrode **18**.

Preferably, the insulators **36** are of the construction disclosed and claimed in the copending application of Raymond G. Herb and James Raatz, Ser. No. 557,729, filed June 15, 1966. Thus, each of the illustrated insulators **36** comprises a series of insulating cylindrical sections **38** interspersed between conductive disks **40**. The insulating components are preferably bonded to the melt components by the method disclosed in the copending application of Raymond G. Herb, Ser. No. 557,787, filed June 15, 1966.

It is preferred to mount equalizing rings **42** on the metal disks **40** of the insulators **36**. The rings **42** are of a diameter corresponding generally to the diameter of the high voltage electrode **18**. Thus, the rings **42** extend around all of the insulators **36**. The provisions of the rings **42** equalizes the potential around all of the insulators and assists in producing a substantially uniform potential gradient along the insulators. The high voltage generator **12** is generally of the construction disclosed and claimed in the copending application of Raymond G. Herb and James A. Ferry, Ser. No. 557,818, filed June 15, 1966. Thus, the high voltage generator **12** comprises an endless charge carrying conveyor **44**, which might be in the form of an endless belt, but perferably comprises a train of charge carrying pellets or beads **46**. Each pellet **46** is preferably made of metal or other conductive material. The pellets **46** are strung together in such a manner that the pellets are insulated from one another. Thus, the pellets **46** may be mounted on an endless insulating cord **48**, or may be connected together by other insulating member so as to form an endless chain.

The conveyor **44** extends between the grounded electrode **28** and the high voltage electrode **18**. Both flights of the endless pellet train are preferably arranged to carry charges to and from the high voltage electrode **18**, so that a high voltage will be built up on the electrode. Thus, for example, positive charges may be carried to the high voltage electrode **18** by one flight of the endless conveyor **44**, while negative charges are carried away from the high voltage electrode by the other flight. The result is to produce a high positive voltage between the high voltage electrode **18** and ground.

At each end of the conveyor **44**, the train of pellets **46** passes around a pulley **50**. At the grounded end of the conveyor **44**, the pulley **50** may be driven by a suitable motor, not shown.

Means are provided to charge the pellets **46** as they depart from the grounded pulley **50**. The charges thus imparted to the pellets are carried to the high voltage electrode **18** where suitable means are employed to transfer the charges to the high voltage electrode. The upper end of the conveyor **44** is housed within the high voltage electrode **18**, so that the charges removed from the pellets will travel outwardly to the outer surface of the high voltage electrode. Means are provided on the high voltage electrode to transfer charges of the opposite sign to the departing pellets. These charges are removed from the pellets when they arrive at the grounded pulley **50**. As shown in FIG. 2, an induction electrode **52** is preferably provided adjacent the grounded pulley to assist in charging the departing pellets. Another induction electrode **54** is provided to assist in discharging the arriving pellets. The charging electrode **52** may be maintained at a high voltage of several thousand volts, for example, by means of a suitable power supply, so that the pellets will be correspondingly charged. Further details of the charging and discharging systems may be obtained by referring to the copending application, Ser. No. 557,818.

The present invention is concerned primarily with the construction of the high voltage accelerating tube **14** and the relationship of the accelerating tube to the other components of the accelerator. The accelerating tube **14** is connected between the high voltage electrode **18** and the grounded electrode **28**, so that the entire voltage developed on the high voltage electrode **18** is impressed along the length of the tube **14**. The high pressure atmosphere of the dielectric gas substantially prevents sparking or flashovers along the outside of the accelerating tube **14**. However, the inside of the tube is maintained at a high vacuum. With prior constructions, difficulties have been encountered with sparking and flashovers within the accelerating tube. Such difficulties have severely limited the working voltage which may be maintained along the length of the tube.

In order to improve the ability of the accelerating tube **14** to withstand high voltages, the illustrated tube **14** is subdivided into a plurality of insulating sections **56**. Isolating diaphragms **58** are provided between the adjacent sections **56**. The diaphragms **58** are preferably made of metal or other conductive material. Each diaphragm **58** is formed with an aperture **60** for the passage of the charged particles. The apertures **60** are preferably located axially in the accelerating tube **14**. As shown, each aperture **60** is formed by a tube **62**, mounted in and extending through the corresponding diaphragm **58**. The tubes **62** are preferably made of metal or other conductive material. The apertures **60** are preferably considerably smaller than the inside diameter of the insulating sections **56**. However, the size of the apertures and the length of the tubes **62** may be varied to a considerable extent. Moreover, the tubes may be eliminated in favor of simple apertures. The isolating diaphragm **58** tend to prevent the propagation of any local sparking or other discharge which may occur along the inner wall of one of the sections **56**. Thus, the diaphragms **58** greatly reduce the chance that a flashover will occur along the entire length of the tube. Such flashovers tend to damage the tube so that the entire accelerator may have to be shut down for repairs.

The insulating sections **56** of the accelerating tube **14** are preferably laminated in construction, as disclosed and claimed in the copending application of Raymond G. Herb and James Raatz, Serial No. 557,729, previously mentioned. Thus, each section **56** preferably comprises a series of insulating rings **64** with conductive layers or rings **66** interspersed therebetween. The insulating rings **64** are preferably made of a ceramic material and are bonded securely to the metal rings or layers **66**. It is preferred to employ the method of bonding disclosed and claimed in the previously mentioned copending application of Raymond G. Herb, Serial No. 557,787.

The insulating sections **56** are clamped or otherwise secured together end to end, to build up the full length of the accelerating tube **14**. Clamping flanges **68** may be bonded or otherwise secured to the ends of the sections **56**, so that they may readily be clamped together.

The upper end of the accelerating tube **14** is clamped or otherwise connected to the ion source **16**, which is mounted within the high voltage electrode **18**. In the illustrated construction, the lower most insulating section **56** is connected to a metal tube **70** which extends out of the tank **20** to the target area, where the specimen to be irradiated by the high energy particles is mounted. Provision is generally made for the insertion of any desired specimen or target into the target area.

As already indicated, a high vacuum is maintained within the accelerating tube **14**. The main vacuum pump or pumps may be connected to the grounded metal tube **70** outside the tank **20**. However, in accordance with the present invention, some or all of the individual sections **56** are separably evacuated by means of a plurality of evacuating devices **72**, connected to intermediate points along the accelerating tube. Preferably, a separate evacuating device **72** is provided for each of the insulating sections **56**, so that the chamber within each section will be separately evacuated. The separate evacuation of the individual sections assists in enabling the accelerating tube to withstand extremely high voltages. Any local sparking or other discharge which may occur momentarily within the accelerating tube may tend to cause the evolution of gases from the walls of the tube. Moreover, the evolution of gases may be caused by mechanical, thermal and other disturbances at local points along the accelerating tube. The separate evacuation of the individual sections insures that any evolved gases will immediately be removed, so that they will not tend to cause a general flashover along the length of the tube.

The evacuating devices **72** preferably take the form of vacuum pumps, but may comprise passive gas absorbing devices containing gettering materials, capable of absorbing gases. Any suitable type of vacuum pump may be employed. However, the pumps are preferably of the ion-getter type, comprising both ionizing means and gettering means. The illustrated pumps **72** are of the orbitron type, as disclosed and claimed in the Herb and Pauly Patent No. 3,244,969, patented Apr. 5, 1966, entitled Electron Orbiting Tubes for Ion Measurement and Gettering Pumps.

The evacuating devices or pumps **72** are preferably mounted on one or more intermediate electrodes **74** which are interspersed between the high voltage electrode **18** and the grounded electrode **28**. The intermediate electrodes **74** are also supported by the insulators **36**, which are divided into sections with the intermediate electrodes therebetween. It will be understood that the intermediate electrodes assume intermediate voltages in accordance with the potential gradient between the high voltage electrode **18** and the grounded electrode **28**.

The intermediate electrodes **74** may assume various forms. As illustrated, each intermediate electrode **74** comprises a cylindrical ring **76** which is mounted between a pair of circular plates **78**. Illustrated evauating devices **72** are mounted within the intermediate electrodes **74**, in the spaces between the plates **78**.

It is preferred to arrange the accelerating tube **14** so that a plurality of the insulating sections **56** are connected between each pair of intermediate electrodes **74**. Preferably, two of the insulating sections **56** are connected together between each pair of adjacent intermediate electrodes **74**. Thus, one of the isolating diaphragms **58** is adjacent each intermediate electrode **74**. Another isolating diaphragm **58** is disposed midway between each pair of adjacent intermediate electrodes **74**.

It is preferred to mount two of the evacuating devices **72** on each intermediate electrode **74**. These evacuating devices are connected separately to the tube sections **56** on opposite sides of the adjacent isolating diaphragm **58**. In the specific construction shown in FIG. 2, a metal ring **80** is connected between the insulating sections **56** at each intermediate electrode **74**. The isolating diaphragm **58** is mounted centrally within the ring **80**. Separate apertures **82** are formed in the ring **80** above and below the diaphragm **58**. The two separate evacuating devices **72** are connected to the separate apertures **82**.

It will be seen that two additional evacuating devices **72** are mounted within the high voltage electrode **18**. One of these evacuating devices **72** is connected to the uppermost section **56** of the accelerating tube **14**. The other evacuating device **72** is connected to the lower end of the ion source **16** to maintain a high vacuum therein.

As already indicated, the evacuating devices **72** preferably comprise vacuum pumps of the orbitron type, as disclosed and claimed in the Herb and Pauly Patent No. 3,244,969. The basic construction of the orbitron pumps is shown in FIGS. 3 and 4. It will be seen that each pump **72** comprises a cylindrical casing or boundary electrode **84**. The interior of the casing **84** is connected to the space to be evacuated, through the aperture **82**. A cylindrical anode **86** is mounted axially in the casing **84**. The anode **86** is preferably in the form of a rod or wire. A positive working voltage is maintained between the anode **86** and the casing **84**, so that a radial electric field will be established therebetween.

Electrons are introduced into the radial field in such a manner that they will travel in spiral orbits around the central anode **86**. The electrons are given initial angular momentum so that they will travel in orbits, rather than traveling directly to the anode **86**. In the illustrated construction, the electrons are injected by means of one or more thermionic cathodes in the form of filaments **88**, disposed parallel to the anode **86** and spaced outwardly therefrom. A shield wire **90** is interposed between each filament **88** and the anode **86**. The shield wire **90** is parallel to both the anode **86** and the filament **88**. Each shield wire **90** has an outwardly bent portion **92** which supports one end of the filament **88**. The other end of the filament is supported by a terminal wire **94**. The shield wire **90** modifies the radial electric field so that a high proportion of the electrons emitted by the adjacent filament **88** will go into orbits around the anode **86**, rather than traveling directly to the anode.

The orbiting of the electrons is further enhanced by a terminating electrode in the form of a sleeve **96**, mounted around the anode **86** and spaced outwardly therefrom, opposite a portion of each filament **88** and shield wire **90**. The terminating sleeve **96** is normally maintained at or near the potential of the outer casing **84**. As shown, the sleeve **96** is mounted on the casing **84**, by means of rods or wires **97**. The shield wires **90** are shown as being connected to a flange **98** on the terminating sleeve **96**. However, the shield wires **90** could be brought out separately.

When the orbitron pump **72** is in operation, a high positive voltage is applied to the anode **86** with respect to the casing **84**. The filaments **88** are heated by causing electrical currents to pass therealong. A high proportion of the electrons emitted by the filaments **88** go into spiral orbits around the anode **86**. Some of the orbiting electrons collide with residual gas molecules in the vacuum space within the casing **84**. The collisions cause ionization of the gas molecules. The positively charged gas ions are driven outwardly to the casing **84** by the electric field between the anode **86** and the casing. Getter material, such as titanium, is provided on the inside of the casing **84** to absorb the ions. The getter material also absorbs unionized molecules, particularly those of the more active gases.

The getter material is preferably deposited on the casing **84** by vaporizing getter material within the casing, so that it will travel outwardly and condense on the casing. The freshly condensed getter material is highly active in its gas absorbing ability. Moreover, the continuously condensing getter material buries the previously absorbed ions and molecules so that they will not be re-evolved.

In the illustrated construction, the getter material is vaporized by heating the anode **86**, which incorporates a supply of the getter material. The preferred getter material is titanium, which is preferably mounted on the anode **86** in the form of a cylindrical slug or other member **100**. Many of the orbiting electrons eventually impinge upon the titanium cylinder **100**. The kinetic energy of the electrons is given up to the titanium cylinder in the form of heat. The titanium cylinder is preferably heated to a temperature at which titanium vapor is evolved directly from the solid titanium by sublimation. However, the temperature of the titanium cylinder is preferably kept below the melting point of titanium, so that liquid titanium will not be present. The titanium vapor from the hot cylinder **100** travels outwardly and is condensed on the relatively cool casing **84**.

It will be evident that electrical power is required to operate the orbitron pumps **72**. Special problems are involved in the derivation of the electrical power because of the high voltages which exist on the intermediate electrodes **74** and the high voltage electrode **18**. Of course, the power could be derived from batteries mounted on the intermediate electrodes **74** and the high voltage electrode **18**. However, electrical power is preferably derived in the manner disclosed and claimed in the copending application of James A. Ferry, entitled Power Transmission System for High Voltage Accelerators. Briefly, the power transmission system comprises a separate electric generator **102** on each of the intermediate electrodes **74**, and also on the high voltage electrode **18**. An electric motor **104** is provided on the grounded electrode **28** to drive the generators **102**. A series of aligned insulating shafts **106** are provided to connect all of the generators **102** to the motor **104**. Thus, the first insulating shaft **106** extends between the motor **104** and the first generator **102**. The other insulating shafts **106** extend between the successive generators **102**.

Each shaft **106** comprises a series of insulating cylinders **108**, with metal disks **110** interspersed therebetween. The insulating cylinders **108** are securely bonded to the metal disks **110**. The insulating components are preferably bonded to the metal components by the method disclosed and claimed in the copending application of Raymond G. Herb, Serial No. 557,797.

The insulating shafts **106** are capable of withstanding the voltage between the adjacent intermediate electrodes **74**, which may be well in excess of 1,000,000 volts. The illustrated accelerator has a potential distribution system which insures that the potential gradient along the insulating shafts **106**, and also along insulators **36** will be substantially uniform. For this purpose, corona discharge electrodes are mounted on the metal disks **40** of one of the insulators **36**. Such electrodes comprise metal disks **112**. Each disk **112** has a needle or sharp wire **114** projecting from one side thereof. Each corona disk **112** is mounted on one of the disks **40** of the insulator **36**. The needle **114** is directed toward the adjacent disk. The high electric field around the needle **114** sets up a corona discharge to the adjacent disk **112**. The successive corona dicharge gaps between the needles and the disks causes a small leakage of current which equalizes the potential drop between the adjacent disks **40** of the insulator **36**. The effect of the successive corona gaps is much the same as would be produced by a series of resistors of high value. Such a series of potential distributing resistors could also be employed, instead of the corona gaps.

To equalize the potential gradient along the insulating shafts **106**, the metal disks **110** on the shafts **106** are arranged to be opposite the disks **40** on the adjacent insulator **36**. Additional needles or sharp wires **116** are mounted on the corona disks **112** and are directed laterally toward the disks **110**. Intermittent corona discharges may occur between the needles **116** and the disks **110**, with the result that the disks **110** are maintained in substantially the same potentials as the adjacent insulator disks **40**. It will be realized that the disks **110** rotate with the shaft **106**, while the needles **116** are stationary. However, the rotation of the disks **110** does not affect the corona gaps between the disks and the needles **116**.

In the operation of the accelerator **10**, the charged particles to be accelerated are directed axially along the accelerating tube **14**. The apertures **60** in the diaphragms **58** provide for the passage of the charged particles, while preventing any substantial flow of gas molecules or non-axial particles between the adjacent sections **56** of the accelerating tube. Any such gas molecules or non-axial particles are continuously pumped by the evacuating devices **72**. It is preferred to provide a separate evacuating device **72** for each section **56** of the tube, so that each section will be separately pumped. In this way, an extremely high vacuum is maintained in all of the sections **56**.

In the illustrated evacuating devices or pumps **72**, the residual gases are ionized by the electrons which are caused to travel in spiral orbits around the central anode **86**. The positive voltage between the central anode **86** and the casing **84** produces a radial electric field, into which the electrons are introduced by the heated filaments **88**. The shield wires **90** and the terminating sleeve **96** cooperate with the filaments **88** in such a manner that a high proportion of the electrons emitted by the filaments **88** are given sufficient initial angular momentum to travel in orbits around the anode **86**, rather than moving directly to the anode.

Some of the orbiting electrons collide with residual gas molecules and cause ionization of the molecules. The positively charged gas molecules are driven outwardly against the casing **84** by the electric field between the anode **86** and the casing **84**. These molecules are obsorbed by the getter material, previously deposited upon the inner wall of the casing.

Many of the orbiting electrons eventually strike the titanium cylinder **86**, which is thereby heated to a high temperature by the electron bombardment. Titanium vapor is evolved by sublimation from the solid cylinder **100**. The vapor is condensed upon the inside of the casing **84**, so as to absorb and bury the gas molecules and ions.

Two of the orbitron pumps **72** are mounted on each of the intermediate electrodes **74**, and also on the high voltage electrode **18**. The pumps are connected to opposite sides of the adjacent diaphragm **58**.

The electrical power to operate the orbitron pumps **72** is provided by the generators **102**, mounted on the intermediate electrodes **74**, and also on the high voltage electrode **18**. The generators **102** are connected to the motor **104** by the series of insulating shafts **106**.

The illustrated accelerator **10** is single-ended, in that the accelerating tube **14** extends only between the high voltage electrode **16** and ground. Thus, the ion source **16** is mounted on the high voltage electrode **18.** The charged particles produced by the ion source are accelerated only once across the high voltage.

Those skilled in the art will realize, however, that the invention is also applicable to double-ended accelerators, of the type disclosed in the copending application of Herb and Ferry, Ser. No. 557,818, filed June 15, 1966. In such double-ended accelerators, the high voltage electrode is mounted between two grounded electrodes by means of two sets of insulators. The accelerating tube extends from the first grounded electrode to the high voltage electrode, and then to the second grounded electrode. The ion source is mounted on the first grounded electrode. Thus, the charged particles are accelerated across the high voltage between the first grounded electrode and the high voltage electrode. Means are provided on the high voltage electrode to reverse the polarity of the charges on the charged particles. The particles are then accelerated a second time between the high voltage electrode and the second grounded support. In this way, the charged particles are accelerated to energy corresponding to twice the high voltage on the high voltage electrode. For the sake of simplicity, the invention has been illustrated in connection with a single-ended accelerator, but the invention is equally applicable to double-ended accelerators.

Because of the division of the accelerating tube into relatively isolated sections which are separately pumped, the tube is highly resistant to flashovers and sparking within the tube. Any local sparking or other stray discharge will not normally be propagated throughout the tube. Thus, the chance of a general flashover is minimized. Any gas which may be evolved in one of the sections due to some local disturbance is quickly removed by the corresponding evacuating device. Due to these factors, the accelerating tube may be used with an extremely high working voltage.

Various other modifications, alternative constructions and equivalents, may be employed without departing from the true spirit and scope of the invention, as exemplified in the foregoing description and defined in the following claims:

I claim:

1. A high voltage accelerator,
comprising a supporting member at essentially ground potential,
a high voltage electrode spaced from said supporting member,
at least one intermediate member spaced between said high voltage electrode and said supporting member,
insulating means connected between said supporting member and said intermediate member and also between said intermediate member and said high voltage electrode,
means for establishing a high voltage between said high voltage electrode and said supporting member,
an accelerating tube connected between said high voltage electrode and said supporting member for accelerating charged particles across said high voltage,
said accelerating tube extending between said high voltage electrode and said intermediate member and then between said intermediate member and said supporting member,
said accelerating tube comprising at least two insulating tubular sections connected end to end,
at least one isolating diaphragm connected between said tubular sections,
said diaphragm having an aperture therein for the passage of the charged particles,
said diaphragm being disposed adjacent said intermediate member,
and at least one evacuating device mounted on said intermediate member and connected to the interior of one of the adjacent sections for separately evacuating said section.

2. An accelerator according to claim **1,**
in which the ends of said sections are connected together at said intermediate member,
said intermediate member having two separate evacuating devices mounted thereon and connected separately to the adjacent sections for evacuating said sections separately.

3. An accelerator according to claim **1,**
in which another separate evacuating device is mounted on said high voltage electrode and is connected to the interior of the adjacent section of said accelerating tube for separately evacuating said section.

4. An accelerator according to claim **1,**
in which a plurality of such insulating sections are connected between said high voltage electrode and said intermediate member.

5. An accelerator according to claim **1,**
in which two of said insulating sections are connected end to end between said high voltage electrode and said intermediate member,
said evacuating device on said intermediate member being connected to the interior of the adjacent one of said two sections,
said high voltage electrode having another evacuating device mounted thereon and connected to the interior of the other of said two sections.

6. An accelerator according to claim **5,**
in which said diaphragm is disposed at said intermediate member,
said first mentioned evacuating device being connected to the interior of the section on one side of said diaphragm,
another separate evacuating device being mounted on said intermediate member and being connected to the interior of the section on the opposite side of said diaphragm.

7. An accelerator according to claim **1,**
in which a plurality of such intermediate members are interspersed between said high voltage electrode and said supporting member,
one such diaphragm being disposed at each of said intermediate members,
each of said intermediate members having two separate evacuating devices connected to the sections on opposite sides of the corresponding diaphragm.

8. An accelerator according to claim **7,**
in which two such insulating sections are connected together end to end between each pair of adjacent intermediate members.

9. A high voltage accelerator,
comprising a supporting member at essentially ground potential,
a high voltage electrode spaced from said supporting member,
at least one intermediate member spaced between said high voltage electrode and said supporting member,
insulating means connected between said supporting member and said intermediate member and also between said intermediate member and said high voltage electrode,
means for establishing a high voltage between said high voltage electrode and said supporting member,
an accelerating tube connected between said high voltage electrode and said supporting member for accelerating charged particles across said high voltage,
said accelerating tube extending between said high voltage electrode and said intermediate member and then between said intermediate member and said supporting member,
and at least one evacuating device mounted on said intermediate member and connected to the interior of said tube for evacuating said tube at the corresponding intermediate point therealong.

10. An accelerator according to claim **1,**

in which another separate evacuating device is mounted on said high voltage electrode and is connected to the interior of the adjacent end of said accelerating tube.

11. An accelerator according to claim **9**,

comprising a plurality of such intermediate members spaced between said high voltage electrode and said supporting member,

and a plurality of such evacuating devices mounted on said intermediate members and connected to the interior of said tube at corresponding intermediate points therealong.

12. A high voltage accelerator,

comprising a supporting member at essentially ground potential,

a high voltage electrode spaced from said supporting member,

insulating means connected between said supporting member and said high voltage electrode,

means for establishing a high voltage between said high voltage electrode and said supporting member,

an accelerating tube connected between said high voltage electrode and said supporting member for accelerating charged particles across said high voltage,

and at least one evacuating device mounted at an intermediate point between said high voltage electrode and said supporting member and connected to the interior of said accelerating tube at a corresponding intermediate point therealong.

13. An accelerator according to claim **12**,

including a plurality of such evacuating devices mounted at different intermediate points between said high voltage electrode and said supporting member and connected to the interior of said accelerating tube at corresponding intermediate points therealong.

14. An accelerator according to claim **12**,

in which said accelerating tube includes at least two sections with at least one diaphragm therebetween,

said diaphragm having an aperture therein to afford passage for the charged particles.

15. An accelerator according to claim **12**,

in which said accelerating tube comprises a plurality of sections with diaphragms therebetween,

each diaphragm having an aperture therein affording passage for the charged particles,

said accelerator having a plurality of such evacuating devices mounted at intermediate points between said high voltage electrode and said supporting member and connected to the interior of said tube at corresponding intermediate points for evacuating said sections separately.

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