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COMBINED ACCELERATOR AND STATIC VOLTAGE GENERATOR

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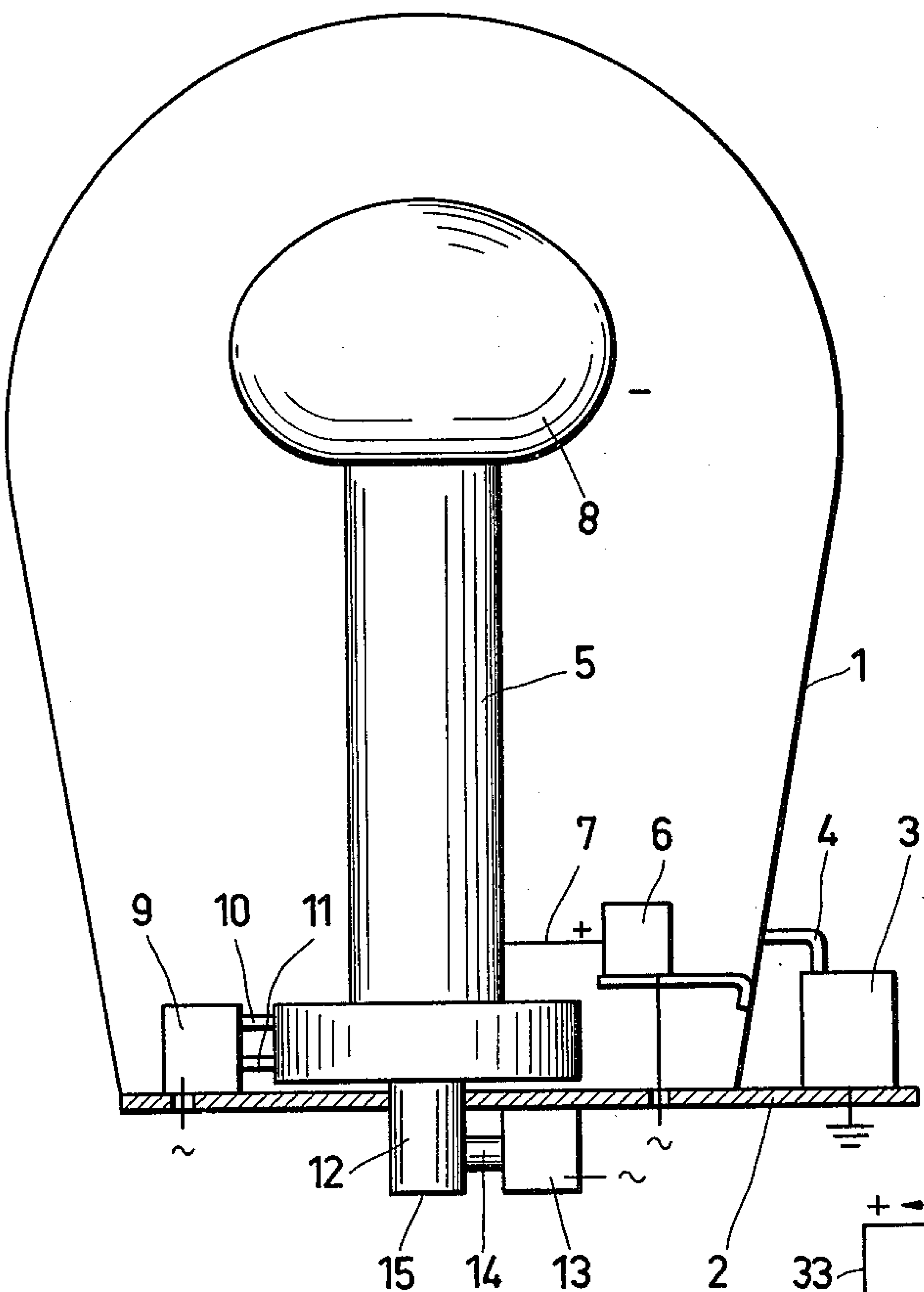
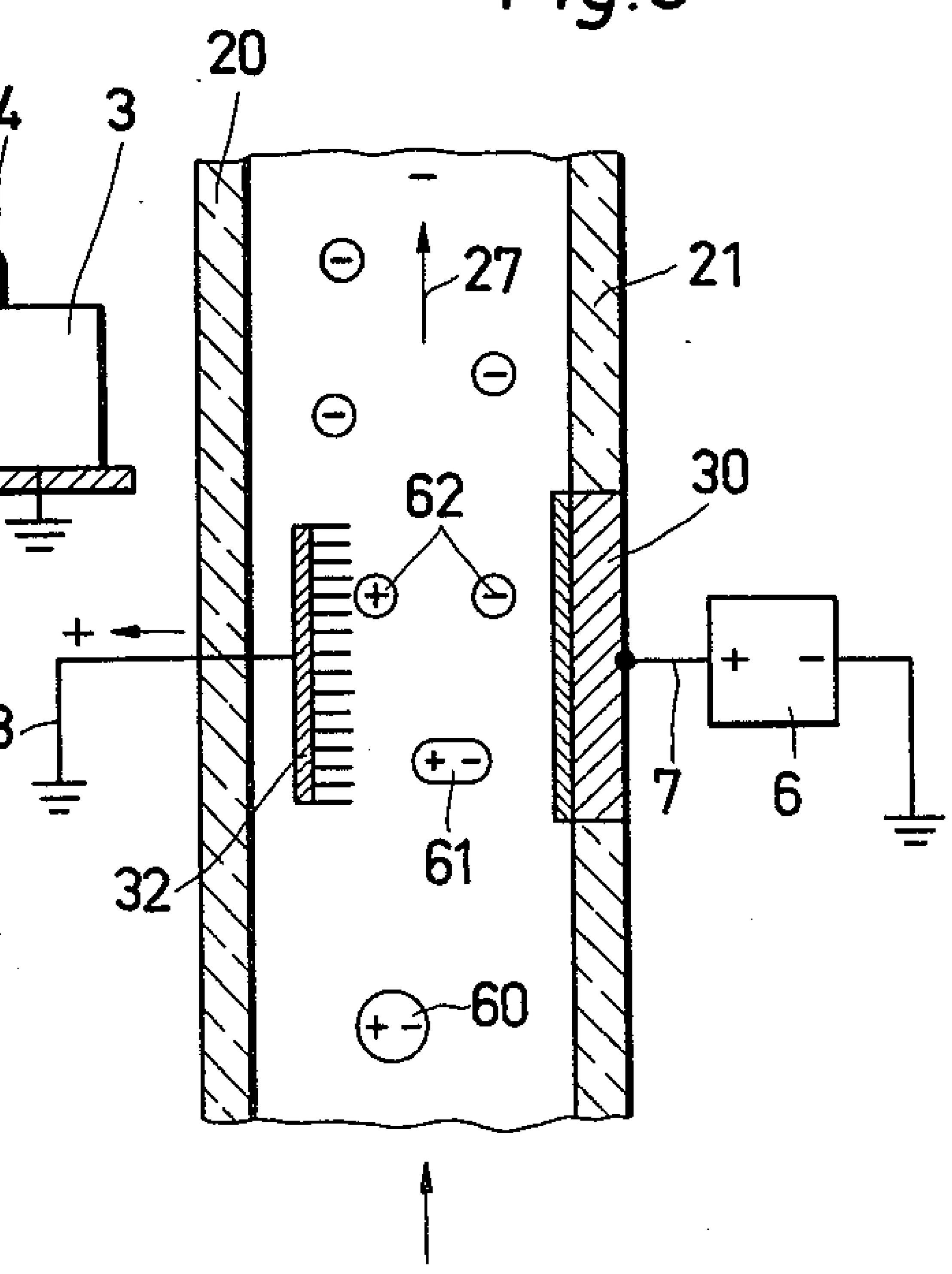


Fig. 1

Fig. 3



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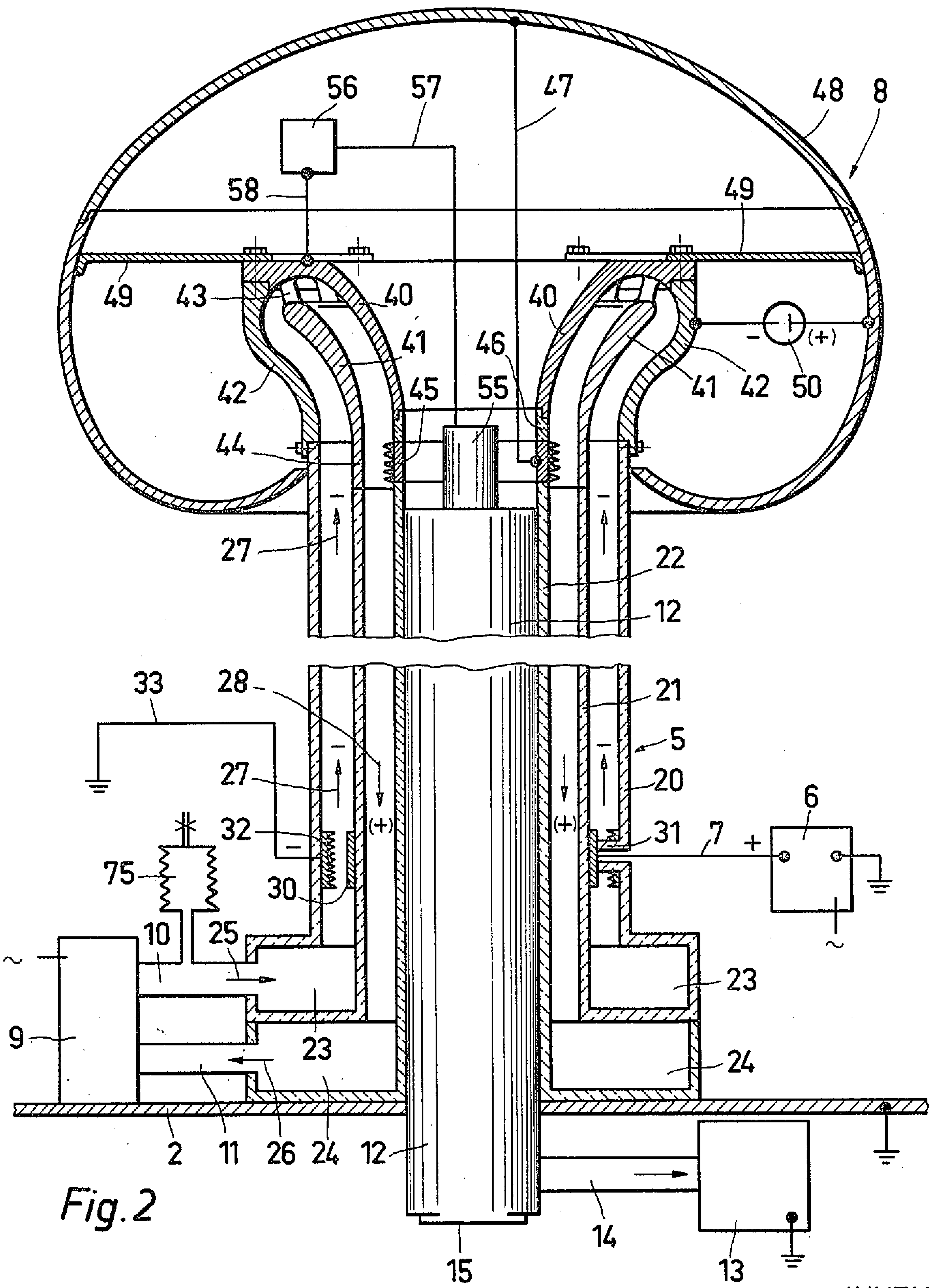

Fig. 2

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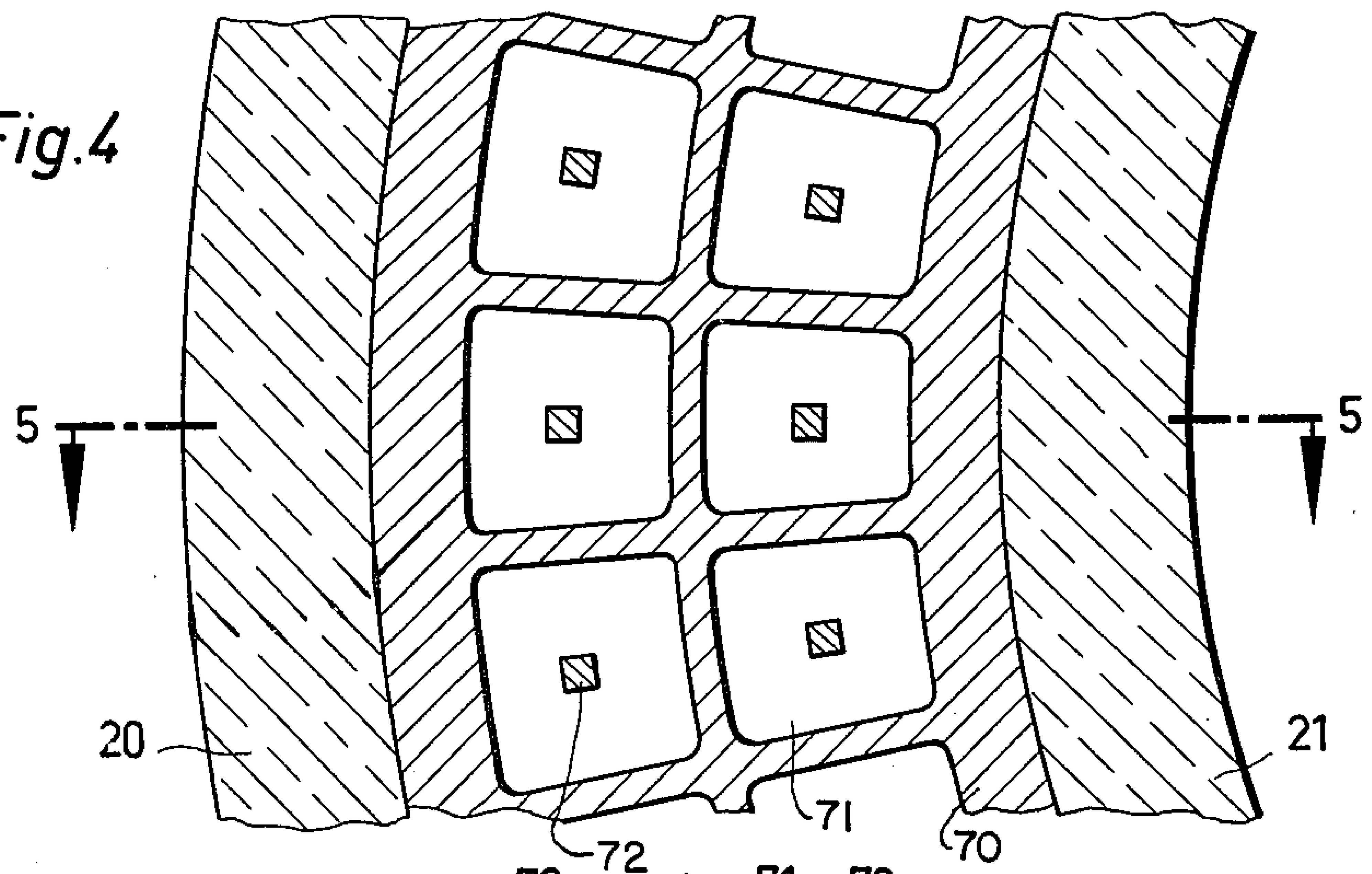
COMBINED ACCELERATOR AND STATIC VOLTAGE GENERATOR

Fig.4



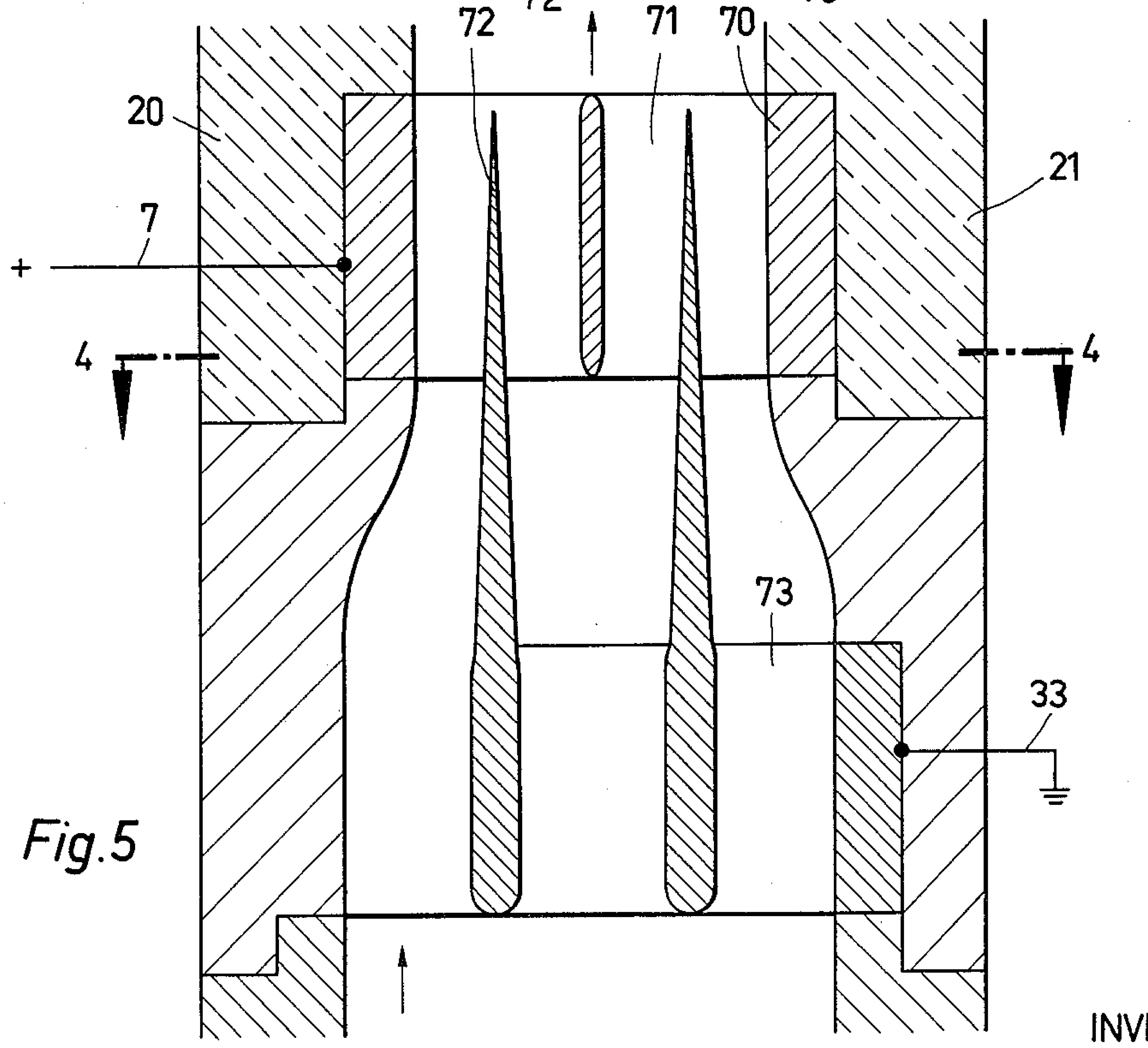


Fig.5

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COMBINED ACCELERATOR AND STATIC VOLTAGE GENERATOR

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This invention relates to devices for the acceleration of atomic particles for the bombardment of matter and similar purposes and more particularly to high-voltage generators employing the static-charge principle of which the Van de Graaf generator is most widely known. In effect, the present invention is a combination of such a high-voltage generator with a particle accelerator.

Generators of the Van de Graaf type permit to achieve high voltages at relatively low cost. However, the current supplied is limited by the charge-transfer mechanism, the width and speed of the belt employed as a charge carrier, and thus the charge density presented to the collecting electrode. The charge density is particularly dependent on the fields set up and on the breakdown stability of the media exposed to such fields. Problems are currently produced by field peaks occurring along the transfer path, and attempts have been made to avoid such peaks and to relocate the fields into dielectrics of high breakdown stability by controlling the potential along the belt, by charging both belt halves at opposite polarities and by mounting the generator in a pressurized vessel filled with a suitable gas.

A noted disadvantage of the belt-type generator is the rapid wear of the belt, the difficult belt guiding, mechanical vibration, and sensitivity to the humidity of ambient air.

In another well-known generator, a non-conductive liquid is pumped through a simple tube system of insulating material and employed as the charge carrier. A space charge is then generated, for instance, by ionization and charge separation in the strong electric fields set up at points; the charge carriers can then be transported in opposition to the effect of an electric field of limited strength. This type of generator yields a rather low current, however, because the breakdown voltage at the weakest point is reached, due to the unfavorable distribution of the field, when the space-charge density is still relatively low.

It is therefore an object of this invention to provide a charge-carrier fluid that is separated into two concentric cylindrical jackets, thus reducing the contribution to the field outside these concentric cylinder jackets coming from the space charge to almost zero.

Another advantage of the present invention is that the space inside the concentric cylindrical charge-carrier arrangement is provided only with a field component parallel to the cylinder axes so that it may accommodate the particle accelerator exposed to a not more than symmetrical field distribution.

Still another advantage of this invention is that the fluid used as a charge carrier provides a relatively high current for the particle accelerator due to the fact that the whole volume of the carrier fluid is utilized to carry the charge.

A special advantage of the invention is that the combination of the high-voltage generator complete with accelerator may be mounted in any position because it is, through its design, independent of the direction of the gravitational field to which it is subjected.

Another advantage of the invention is that the combination of static generator and accelerator is independent of any force of acceleration to which the combination may be subject.

The features of this invention will become apparent from a discussion of the physical principle on which the invention is based.

Let us assume that two coaxial tubes of an insulating material have static charges of equal magnitude, but opposite polarity. If now the two tubes are rotated around their common axis, but in opposing senses of rotation, a charge transfer will take place. If a voltage greater than that required for excitation is to be generated, the said two tubes would have to be separated for charging and discharging, that is, once they are charged, they will allow for a voltage amplification only once.

Now the rigid coaxial tubes may be made in the form of flexible, elastic hoses. Two such concentric hoses may be pictured of equal length and welded by their circular ends to each other so that they now form a double-wall hose. This endless thin-wall body may be thought of moving with its inner wall along one of its axial directions and with its outer wall in the other direction of the longitudinal axis. Each time the direction of motion is reversed, the diameter of this body is changed and the endless hose is charged and discharged, respectively.

Owing to the incessant deformation required, it would be found difficult to design or operate such arrangement. However, the charge motion along the inner wall of the hose in one direction and along the outer wall in the other direction of its longitudinal axis offers the great advantage of setting up almost no electric leakage field outside this endless hose.

A feature in this invention is that this advantageous operation is brought about by the use of a fluid performing the motions above described and representing an endless charge carrier. In the simplest case in accordance with this invention, an insulating fluid is therefor used. Very fine charge carriers, as metal particles of microscopic size, may be admixed to the fluid.

Another feature of this invention is that this fluid is shaped into an endless double-wall hose shape by concentric tubes of insulating material. A pump forces the fluid in one direction of the longitudinal axis of the arrangement of the inner and the intermediate tube; by the same force, the fluid reverses the direction of its motion at the far end of the tube arrangement and returns in the other direction, this time in the space between the intermediate and the outer one of the total of three concentric tubes. This motion is repeated as long as the fluid pump is in operation. In the vicinity of the tube ends or faces, the charge-carrier fluid is charged and discharged, respectively, with the aid of special devices that will be described below in connection with an embodiment.

A distinct feature of this invention is that the electric field of the charge thus carried, is concentrated to the inner volume of the carrier fluid and in the intermediate tube forming the "turning point" for the two directions of motions of the fluid parallel to the longitudinal axis or center line of the three concentric tubes.

A feature of this invention is also that the space charge is thinned out in thin layers; hence, the maximum field strength permissible is not reached until the space charge is of much higher density than in conventional designs. Although the weight rate of flow is the same as in conventional design, the current obtained is higher accordingly.

In general, the invention provides a column of three concentric tubes. In the space between the outer and the intermediate tube, the carrier fluid flows, say, towards the top. At the base of the column, the fluid is charged; the base is connected to ground. Close to the base of the column is a pump for the flow of the fluid. The charge is collected at the upper end of the column; here the electrode to be charged is mounted and connected to the high-voltage end of the particle accelerator accommodated inside the column. The magnitude of the voltage so generated depends, as is well-known, on the distance between the upper electrode and its insulator, and on the brush-discharge and breakdown loss occurring at a high voltage. It also depends on the current consumed in the central particle accelerator. To reduce the overall loss, the whole generator-accelerator combination is placed into a gas-filled pressurized vessel.

The fluid reaching the top end of the column, gives up its charge to the upper electrode, is re-directed, and flows downwards in the space between the intermediate and the inner tubes of the column. During this downward flow, the fluid may be used to carry a charge of a polarity opposite to the above-described charge. The fluid then arrives at the lower end or base of the column and is discharged there, preferably in the fluid pump. After that, the fluid is ready to take a new charge.

Further details of the present invention pertain to the particular construction and arrangement of the individual parts thereof. It will be understood that various modifications may be made therein and it is intended to cover in the appended claims all such modifications as fall within the true spirit and scope of the present invention.

For a description of an embodiment of this invention in greater detail, reference is made to the following specifications and the attached drawings wherein like reference numerals refer to the same parts throughout, and in which:

FIG. 1 is a schematic of the front elevation of the voltage generator and accelerator combination accommodated in a pressurized vessel,

FIG. 2 is a sectional view of the combined voltage generator and particle accelerator,

FIG. 3 is a schematic presentation of the charging of the carrier fluid,

FIGS. 4 and 5 are the sectional and cross-sectional views of a portion of the charging or discharging device, respectively.

Referring first to FIG. 1, the pressurized vessel **1** is sealed by the base plate **2** and is fed by the device **3** with dry nitrogen gas under pressure through the connecting pipe **4**. The insulation and brush-discharge loss is reduced accordingly. Mounted inside the vessel **1** is the column **5** of concentric tubes, mounted in fixed relation to the baseplate **2**. The voltage generator **6** supplies, by the feeder **7**, the charge to the carrier fluid. In the example shown, it supplies a positive voltage of, say, 10 kilovolts. With the aid of the column **5** and the charging and discharging devices below described, the upper electrode **8** is charged negatively. The fluid is forced to circulate upwards and downwards by the fluid pump **9** connected to the column **5** by pipes **10** and **11**. The particle accelerator **12** is mounted inside the column **5**; its lower, grounded end protrudes through the baseplate **2** and is connected to the high-vacuum pump **13** by the vacuum line **14**. The accelerated, positively or negatively charged particles emerge through a window or an aperture in the accelerator base **15**. The voltage generator **6**, the fluid pump **9**, and the vacuum pump **13** are operated from a mains voltage or alternating current as indicated.

FIG. 2 shows a sectional view of the concentric high-voltage generator and particle accelerator. The column **5** comprises the outer tube **20**, the intermediate tube **21**, and the inner tube **22**. The tubes are made of an insulating plastic and may be assembled by cementing or welding. The space between the outer tube **20** and the intermediate tube **21** communicates with a ring-shaped chamber **23** while the space between the intermediate tube **21** and the inner tube **22** communicates with the ring-shaped chamber **24**. Interconnected between these spaces is the fluid pump **9** which causes the fluid to flow in the directions indicated by the arrows **25** and **26**. The carrier fluid flows between the concentric tubes **20, 21,** and **22** in the directions of the arrows **27** and **28**. The intermediate tube **21** carries on its outer side near the chamber **23** the smooth metal ring **30** charged by the auxiliary voltage generator **6** via the feeder **7**. This feeder **7** leads through the insulating tube **31**, which is guided through the outer tube **20** to the intermediate tube **21**. The electrode formed by the smooth metal ring **30** faces the ring-shaped electrode **32** at the inside of the outer tube **20**. This electrode **32** is equipped with sharp points or edges; it is grounded by the line **33**. Through the interaction of the two electrodes, the carrier fluid becomes negatively charged as shown by arrow **27**.

In other words, the carrier fluid flowing upwards between tubes **20** and **21** as indicated by arrow **27** carries a negative charge, the charge being concentrated to the inner volume of the carrier fluid. To accomplish the objects of the present invention, the charge-carrier fluid must exhibit the following properties: its electric resistance as well as the dielectric constant and the breakdown-stability must be high, whereas the mobility of the charge carriers and the transformation of energy within the carrier fluid should be kept small. In view of losses due to skin friction it may be advantageous to employ thixotropic materials capable of reversible thixotropy. Finally, the carrier fluid may also contain suspended particles, particularly semiconducting and/or metal-conducting particles, which particles serve to carry the electric charge. Such suspended particles may be admixed to the charge-carrier fluid in a manner known per se.

The upper end portions of tubes **20, 21,** and **22** extend into the reversing system comprising the metal portions **40, 41,** and **42**. This system serves to direct the charge-carrier fluid downwards toward the pump. The center portion **41** is connected with the inner portion **40** by way of holding means **43**. At the point where the flow of the carrier fluid is reversed the fluid gives off its negative charge to the metal portions **40, 41,** and **42**, thus charging these portions negatively. In the embodiment shown in FIG. 2 the center metal portion **41** extends very far downwards, and is integral with an annular member **44** similar to the annular member formed by the ring-shaped electrode **30**. The annular member **44** faces an electrode **45** which, similar to electrode **32**, is provided with points. The electrode **45** is an extension part of the inner tube **22**. A tubular insulating member **46** is inserted between the pointed electrode **45** and the inner metal portion **40**. The electrode **45** provides the carrier fluid with positive charge as indicated by the arrow **28**, and these charges are released in the grounded pump **9**.

Electrode **45** is connected to a thin-wall metal sphere **48** by way of line **47**. Sphere **48** serves to reduce brush-discharge losses and is carried by the metal portion **40** by means of insulating supporting members **49**. Between sphere **48** and metal portions **40, 41,** and **42** a brush-discharge path **50** is inserted which serves to limit the voltage difference between the sphere and the metal portions to a particular value, say 20 kv., adjustable as at **50**.

Due to the charge reversal of the charge-carrier fluid at electrodes **44** and **45** the potential of sphere **48** is positive with respect to the metal portions **40**, **41**, and **42**, thus considerably reducing the brush-discharge losses.

Within the innermost tube **22** an accelerating tube **12** is arranged, for accelerating a flow of charged particles in a manner well-known to those skilled in the art.

The upper end of the accelerating tube is opposed to the grounded outlet end **15**. Next to the upper end, to which a high voltage is applied, a source **55** of particles is arranged, which source may be either an electron emitter or an ion source of conventional design, as the case may be. The electron emitter or ion source receives the required voltages, etc. from an auxiliary device **56** via line or lines **57**. The auxiliary device **56** is disposed within the spehere **48** and connected to the potential of the metal portion **40** by way of line **58**. Tube **21** forms a separating wall between the two oppositely charged flows **27** and **28** of the charge-carrier fluid. According to the embodiment shown in FIG. 2, the charge collecting on both sides of the insulating separating wall is carried off by increasing the conductivity of the separating wall at right angle to the longitudinal axis of the wall either across the entire wall or at certain points thereof. To this end, small passages may be provided, for instance, permitting the charges to neutralize each other. These passages may also be lined with a material having a conductivity greater than that of the wall material. To control the potential for a discharge tube arranged in the interior, the tubes, preferably the innermost tube, may be provided with a certain conductivity along the generating lines.

FIG. 3 is a schematic view showing the charging of the carrier fluid. The fluid enters the shown section of the space between tubes **20** and **21** from below. At this moment each particle of the carrier fluid is neutral, that is, in a particle **60** both charges are arranged closely side by side so that they counterbalance each other. As soon as this particle, for instance, a chargeable molecule, gets between the electrodes, the two charges will move somewhat apart as indicated at **61**, since at that place they are exposed to the effect of the field between the electrodes. Owing to the effect of the points on electrode **32** the positive charge will be torn off, as indicated at **62**, and be grounded via line **33**. Consequently, the charge-carrier fluid flowing towards the top will be negatively charged. Whether the fluid will be negatively or positively charged, depends on the charge supplied by the auxiliary voltage generator **6** to the smooth electrode **30**. Thus, if that generator should provide a negative charge, contrary to the example illustrated in FIG. 3, the charge-carrier fluid will be positively charged. Accordingly, the metal portions **40**, **41**, and **42** (FIG. 2) will also be positively charged. Thus it is possible to reverse the polarity of the entire apparatus by simply reversing the polarity of the auxiliary voltage generator. Although the carrier fluid could also be charged with the aid of the auxiliary voltage, so that the voltage generator could be dispensed with, yet the presence of that generator and the polarity thereof positively determine whether the electron emitter or ion source **55** (FIG. 2) has a positive or negative potential with respect to ground.

FIGS. 4 and 5 show a real embodiment of electrodes **30** and **44**, respectively, and **32**, and **45**, respectively. According to this embodiment, electrode **30** comprises a ring-shaped metal member **70** having two rows of circular-arranged holes **71** of substantially square shape. Electrode **32** is composed of square needles **72** carried by a needle holder **73**. In this case, the sharp edges of needles **72** constitute the points of the electrode.

In FIG. 2 an expansion vessel **75** is connected to the circulation system of the charge-carrier fluid. This vessel is completely filled with fluid, thus containing no air bubbles. The expansion vessel **75** is designed as metal bellows so that the thermal expansion of the carrier fluid may be balanced.

Due to the symmetrical arrangement of the apparatus and the utilization of a charge-carrier fluid the apparatus may be mounted in any position and is wholly independent of accelerations acting thereon.

Having thus fully disclosed our invention, what is intended to be secured by Letters Patent is:

1. A static voltage generator comprising, two concentrically arranged passages, one of said passages having an inlet at one end, the other one of said passages having an outlet at one end, and the two passages being in communication with one another at their other ends, means for supplying a charge carrier fluid under pressure to said inlet and for removing the fluid from said outlet whereby the generated voltage charge is carried through the two passages, and voltage generating means adjacent said inlet for electrically charging the fluid supplied, and electrode means adjacent said other ends for withdrawing the charges carried by the fluid.

2. The static voltage generator of claim 1, wherein three concentrically arranged, vertically extending tubes of insulating material constitute said two passages, said inlet communicating with the outer one of said passages and said outlet communicating with the inner one of said passages.

3. The static voltage generator of claim 2, wherein a portion of one of said tubes in one of said passages is grounded at said one end, the voltage generating means including an electrode in said one passage and isolated from said portion, and further comprising an auxiliary voltage generator connected to said electrode for supplying a voltage thereto, and said electrode means adjacent said ends include metallic members adapted to receive the charge from the carrier fluid and arranged at the other ends for guiding the charged carrier fluid from one to the other passage.

4. The static voltage generator of claim 3, wherein said electrode means further include another charging means for charging the carrier fluid flowing in the second passage, said other charging means being arranged adjacent said other end of the second passage.

5. The static voltage generator of claim 2, further hermetically sealed vessel spacedly enclosing said tubes, and a gaseous fluid under pressure filling said vessel.

6. A static voltage generator comprising three coaxial tubular members radially spaced from each other so as to define two coaxial annular passages therebetween, said tubular members being of electrically insulating material; two chamber means axially spaced from each other and connecting respective axial end portions of said passages; pump means for axially circulating a fluid through said passages and said chamber means, whereby said fluid flows in one axial direction in one of said passages, and in an opposite axial direction in the other passage, said passages and chamber means jointly constituting a closed fluid circuit; electrical charging means in one portion of said circuit operative for charging a circulated fluid with a charge of predetermined polarity, and charge collecting means in another portion of said circuit spaced from said one portion in the direction of flow of said fluid for collecting the charge from the flowing charged fluid.

7. A static voltage generator as set forth in claim 6, wherein said charge collecting means include means for charging said fluid in said other portion of said circuit with an electric charge having a polarity opposite to said predetermined polarity, and means for releasing said opposite charge intermediate said other portion and one portion of said circuit.

8. A static voltage generator as set forth in claim 7, wherein said tubular members are substantially cylindrical.

9. A static voltage generator as set forth in claim 7,

wherein one of said chamber means is of conductive material and constitutes a portion of said collecting means.

10. A static voltage generator as set forth in claim 7, wherein said means for charging said fluid in said other portion of said circuit include a metallic member spacedly enveloping said chamber means of conducting material and electrode means in said other circuit portion conductively connected to said metallic member, and brush discharge means interposed between said metallic member and said chamber means of conducting material.

11. A static-voltage generator as set forth in claim 7, wherein said collecting means are axially spaced from said charging means and said releasing means in the same direction.

References Cited by the Examiner

UNITED STATES PATENTS

2,308,884	1/43	Lindenblad	310—5
2,578,908	12/51	Turner	328—233
2,677,774	5/54	Nygard	310—5
2,820,142	1/58	Kelliher	328—233
2,945,141	1/60	Van de Graaf	313—62

FOREIGN PATENTS

812,996	2/37	France.
1,088,601	9/60	Germany.

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