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[54] **HIGH VOLTAGE GENERATOR**
**13 Claims, 4 Drawing Figs.**


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[51] **Int. Cl.** .......... **H02n 3/00**
[50] **Field of Search** .......... 310/5, 6, 10, 11; 103/1



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**ABSTRACT:** An ionized, dielectric fluid flows into a series of ion transport passageways which extend adjacent to each other and which taper outwardly in the direction of fluid flow. The passageways are fabricated from material which is slightly electrically conductive to preclude charge build up on the passageway walls. Ions arriving at the high voltage electrode are collected by collector without the use of an external power supply. The collector has a large surface area relative to an emitter electrode so that an electric field is developed between the collector and the emitter electrode for producing ions of the opposite sign in the fluid. The oppositely ionized fluid flows into the next passageway where the ion collection process is repeated. A high potential which builds up on the emitter electrode renders the device useful as a high voltage generator.


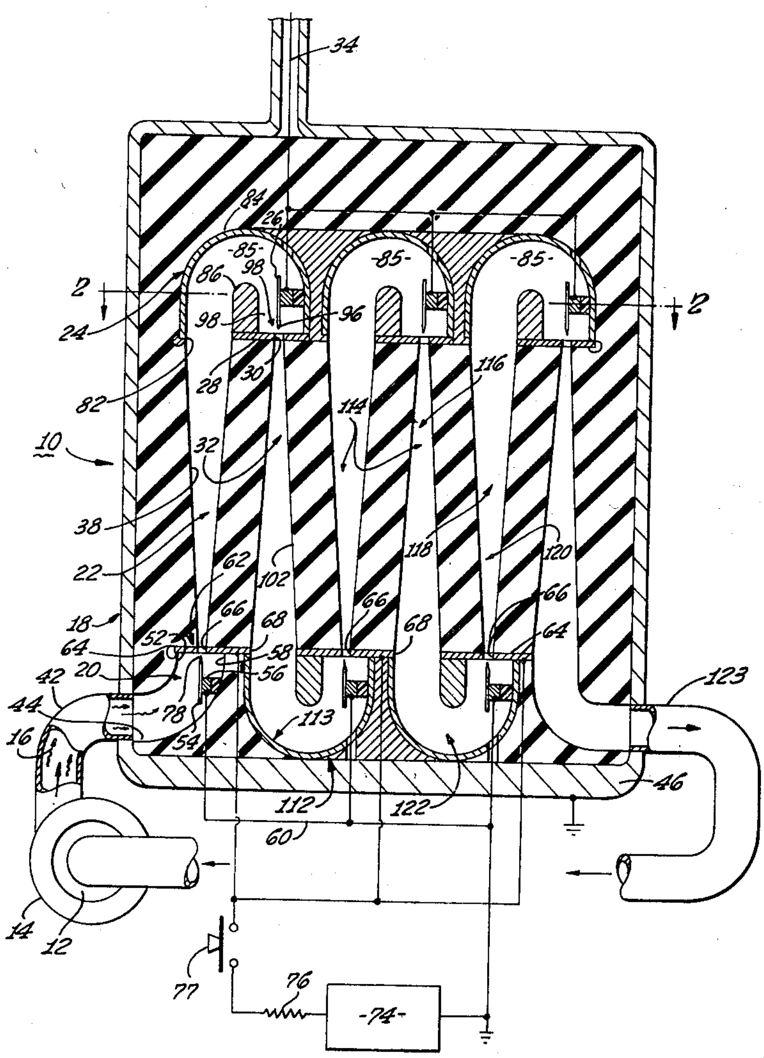

Fig. 1

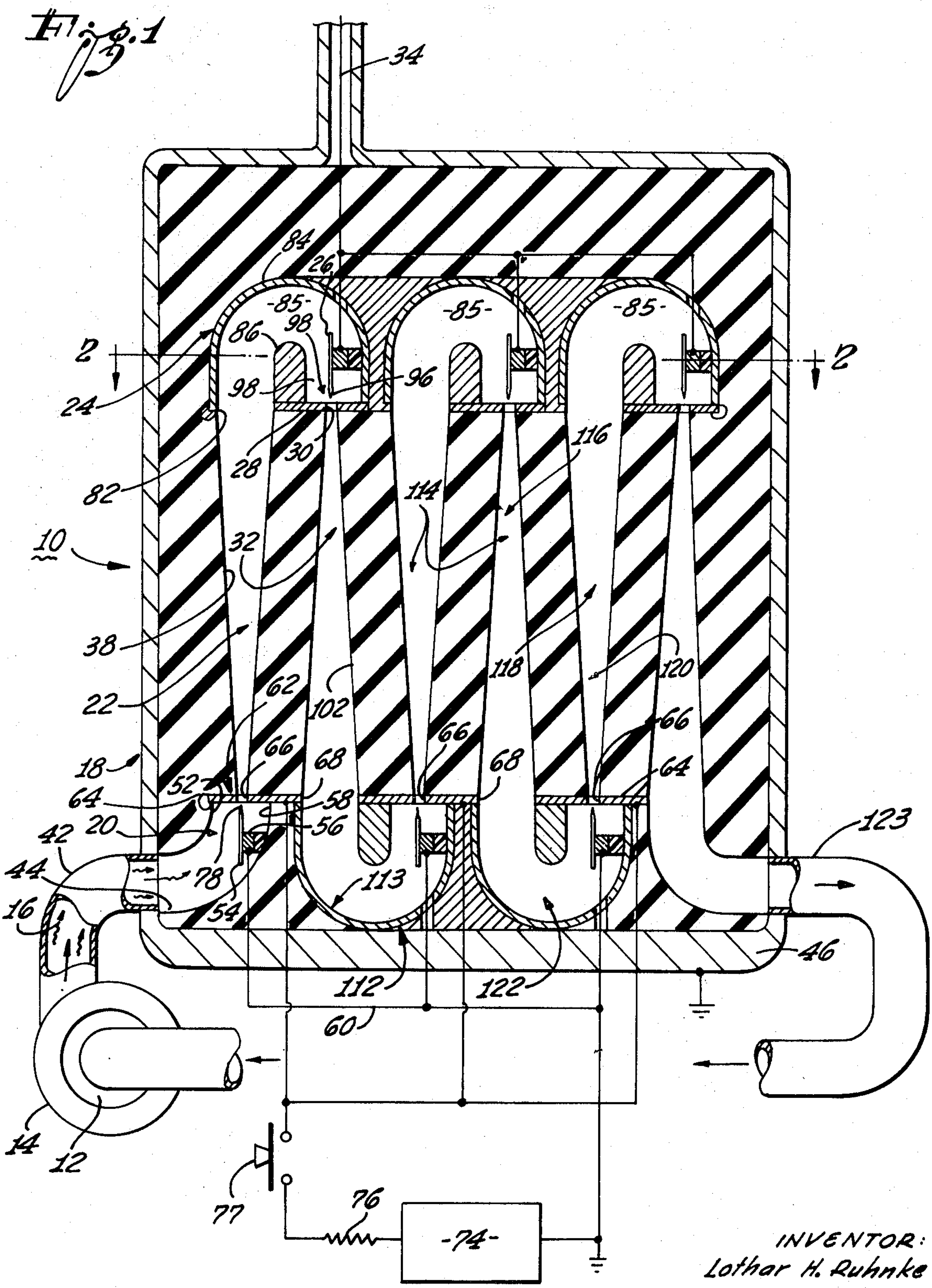


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Fig. 2

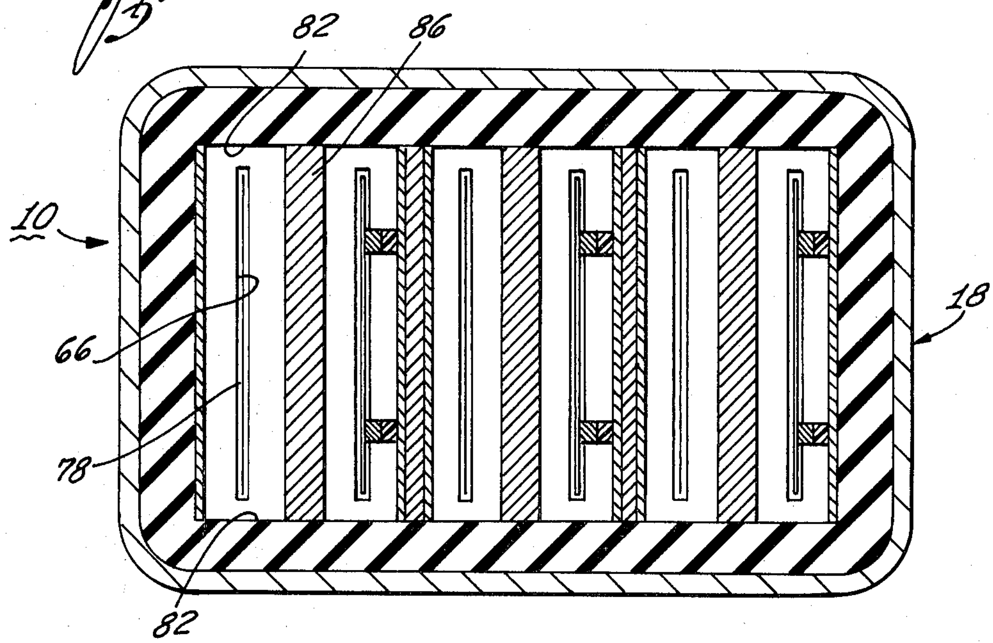



Fig. 3

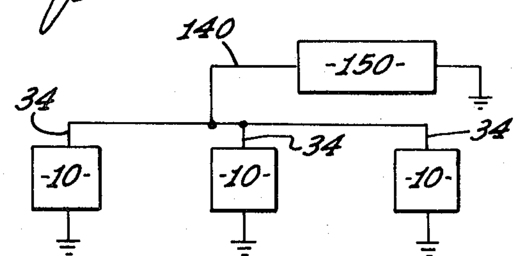
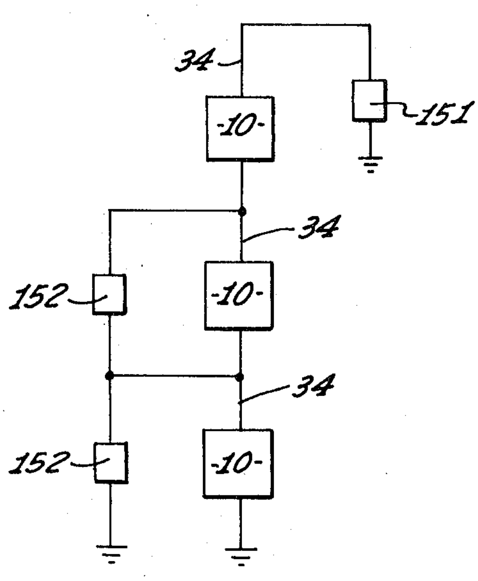



Fig. 4

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# HIGH VOLTAGE GENERATOR

## BACKGROUND OF THE INVENTION

This invention relates to a high voltage generator and more particularly, to a self-exciting, high voltage generator utilizing a highly insulating fluid flowing through a tortuous series of tapered, ion transport passageways and a series of improved ionizers. The highly insulating fluid is used as a means of transporting ions of a given sign to, and ions of an opposite sign from, an output electrode which is raised to a high potential during the operation of the generator. The improved ionizers produce the ions which are transported utilizing the principle that a fluid passing through a strong electric field generated by a sharp point or edge will be ionized and will acquire a charge of the same sign as the potential of the sharp edge or point relative to a nearby conducting surface.

In the past, various high voltage generators have been suggested. Charge transport fluids in such generators have been aerosol, gaseous and liquid. Extensive analysis, experimentation and investigation into such prior high voltage generators indicates that the foregoing principle may be used for high voltage generation. Applicant's research has indicated, however, that such prior high voltage generators have not achieved commercial acceptance because certain basic factors in high voltage generator design have been overlooked. As an example, it has been found that the efficiency of such generators is limited by the existence of an unneutralized electric field caused by the presence of a large number of ions of a given polarity flowing along the channel. This field forces many of the ions from the stream thereby reducing the total current delivered. Hence, the output current of such prior high voltage generators is limited. It is known that the output current of such high voltage generators is determined by the fluid flow rate and the space charge density in the ion transport passageway. In a single stage of such a high voltage generator, it is not possible to generate infinitely high output current because the space charge density in the ion transport passageway is limited by the electric field it generates, the geometry of the ion transport passageway, the breakdown properties of the fluid, and the flow rate of the fluid. Further, the flow rate of the fluid is limited because its charge carrying capacity diminishes when cavitation develops and tends to produce arcing across the electrodes of the ionizer. On the other hand, the fluid flow rate cannot be too low because a minimum rate is required to flush out of the ionizer a desired percentage of ions which are produced.

A critical consideration in the operation of such a high voltage generator is the operating efficiency. Considering a typical desired electrical output of 1,000,000 volts in a generator operating at a space charge density ($q$) of 0.07 coulombs per cubic meter, then the electrical pressure would be 10 p.s.i. This means that for an efficiency of 50 percent, the mechanical pressure drop must be limited to 10 p.s.i., which is a relatively low pressure drop. The allowable mechanical pressure drop becomes important when the fluid is liquid and when one attempts to provide a fluid pump which operates against relatively low pressures at the flow rates required. The characteristics of available liquid pumps generally make it advantageous to cascade the fluid flow paths which has led to electrical breakdown and generator size problems in the past.

In the operation of such prior high voltage generators, while a high electric field is being produced in the direction of the ion transport passageway, a radial electric field is produced by the space charge in the passageway which tends to dissipate the ions radially. Such prior generators have used ion transport passageways fabricated from electrical insulators having very high insulating characteristics. Because of the radial field, ions move toward the walls of the passageway and, as a result of the high insulating characteristics of the passageway material, no appreciable current flows through the walls, hence, a charge builds upon the walls. Because of the lack of current flow through the walls, the charge which builds up on the walls soon exceeds the voltage at which wall breakdown and sparking occur. Sparks may follow a path along the wall in a direction parallel to the longitudinal field or may tend to move radially across the wall. In either case, sparks deposit on the wall a thin conductive film, such as carbon if the wall is plastic, which film provides an easier path for arcing upon the occasion of the next breakdown. As more breakdowns occur, the conductive deposit builds up and produces a short circuit path from the ion collector to ground or a short circuit through the wall to ground or to an adjacent fluid channel. In either situation, the walls are permanently damaged and must be replaced.

In an attempt to reduce the space charge density in the ion transport passageway and to lessen the charge buildup and breakdown problems, it has been suggested to use relatively wide ion transport passageways. However, overall efficiency is reduced significantly in this manner because the fluid volume flow rate must be increased to carry the same number of ions to the ion collector.

Another limitation in such prior high voltage generators which relates to the high longitudinal electric field has been the relatively low breakdown voltage between the ion collector and the collector electrode of the ionizer. Such low breakdown voltages result from the configurations of the electrodes in the ionizer which in the past have provided many relatively sharp metal elements at which the electric field concentrates. For example, in high voltage generators in which a charged aerosol is fed through a tube into an ion transport passageway, the tube provides a relatively sharp location at which the electric field lines concentrate. The concentrated electric field lines reduce the breakdown voltage between the tube and an ion collector, hence, the maximum voltage which the generator can generate is limited. Further, in other high voltage generators, large apertures, such as those formed by annular rings, are used as collector electrodes in conjunction with pointed emitter electrodes. In such case, the electric field concentrates at the ring and substantially reduces the breakdown voltage. Applicant's extensive investigation and experimentation indicates that the collector electrode of the ionizer should be in the form of a relatively small cavity containing a flat plate positioned more or less perpendicular to the fluid flow path so that it blocks the flow path, except for a small opening to permit the escape of fluid at high velocity.

Further, in prior high voltage generators, it has been customary to use ion collectors having large surface areas for collecting the ions transported through the ion transport passageway. The operating principle of such collectors is based upon the fact that if an ionized fluid remains in a container long enough Coulomb forces will cause the ions to diffuse or move to the surfaces of the ion collector. However, for this type of operation, applicants have found that the collector volume must be of the order of 1 cubic meter per milliampere of output current produced. Thus, for a high voltage generator having an output of 10 milliamperes, one would need a 10 cubic meter volume just for the ion collector. At a specific gravity of .89 of a suitable liquid carrier fluid, such as transformer oil, the collector would contain 19,580 pounds of fluid, which is clearly a prohibitive weight.

## SUMMARY OF THE INVENTION

Research involving a careful study of the problems associated with such prior high voltage generators indicates that such problems can be eliminated or reduced to insignificant proportions by a device constructed according to the principles of the present invention. A plurality of ion transport passageways are used wherein adjacent passageways transport fluid flowing in opposite directions and carrying ions of opposite sign. This results in the elimination of the overall electric field produced by the net space charge and greatly reduces the diffusion of ions to the walls of the passageways. Reduction of ion diffusion to the walls also tends to reduce the danger of internal arcing. This difficulty is further reduced when the ion transport passageways are fabricated from a slightly conductive, electrically insulating material. Rather than forming high potential differentials on opposite sides of a highly insulating wall, the slightly electrically conductive insulators conduct a small current. The conduction is sufficiently small that it does not cause a serious loss of output current while it prevents breakdown along or through the walls of the fluid passageway so that should the output voltage be uncontrolled, ultimate breakdown occurs in the fluid. Such breakdown in the fluid is more desirable because it does not produce a conductive deposit on the walls and does not lead to destruction of the walls.

Further, in another embodiment of applicant's invention, an improved high voltage generator may include ion transport passageways having cross-sectional areas which increase with increased distance along the fluid flow path. This achieves:

1. a near zero overall space charge density even though the space charge decreases as the ionized fluid flows down an individual channel, and
2. a diffuser section providing a reduced fluid velocity and larger cross section area to decrease the pressure drop per unit travel distance in the liquid prior to passage of the liquid through a subsequent ionizer.

In one embodiment of the present invention, the functions of collecting ions of a given sign and producing ions of a sign opposite to the given sign are performed by an improved ionizer which uses an ion collector which is small relative to those used in prior high voltage generators. The ion collector is located at the downstream end of an ion transport passageway and collects a portion of the incoming ions from the fluid. The fluid passes through a slot in a flat plate electrode section of the ion collector and into the next passageway. The number of ions collected by the collector greatly exceeds the number collected by an emitter electrode having one or more sharp points or edges positioned adjacent to the slot so that an electric field is developed in the space between the sharp edge and the flat plate electrode. The electric field produces ions of a sign opposite to the sign of the ions which were collected by the collector. Ions of opposite signs combine and the excess ions of the opposite sign to that flowing into the collector will flow with the fluid through the next passageway and will complete the collection by neutralization of the remainder of the incoming ions.

An object of the present invention resides in a new and improved high voltage generator.

Another object of the present invention is to provide a high voltage generator in which spark erosion of passageways for guiding dielectric fluid is eliminated.

Still another object of the present invention resides in the provision of ion transport passageways which are tapered to provide the same ion density per unit length of the passageways.

Yet another object of the present invention is to provide an ion collector and fluid ionizer which is effective to reverse the polarity of ionization of a dielectric fluid while generating a high voltage without the use of an insulated power supply in the high voltage area.

## DESCRIPTION OF THE DRAWINGS

Other objects and advantages of the present invention will become apparent from the following detailed description when considered with the accompanying drawings in which:

FIG. 1 is an elevational view taken in cross section of the high voltage generator of the present invention illustrating a plurality of generally parallel, tapered ion transport passageways spaced by ion collectors where a high potential is developed;

FIG. 2 is a cross-sectional view taken along line 2–2 in FIG. 1 showing emitter electrodes which are connected to a high voltage output terminal;

FIG. 3 is a schematic view illustrating a number of the high voltage generators of the present invention connected in series; and

FIG. 4 is a schematic view showing a plurality of the high voltage generators of the present invention connected in parallel.

## DESCRIPTION OF THE DISCLOSED EMBODIMENT

Referring now in general to the drawings, there is shown in FIG. 1 an improved high voltage generator 10 constructed according to the principles of the present invention. The advantageous features of the high voltage generator 10 may be illustrated with any of the commonly used working fluids such as insulating or dielectric liquids, gases and aerosol laden gases. The actual choice of an ion transport fluid for the generator 10 will result from considerations such as voltage range to be produced, current requirement, type of power available, etc. For purposes of illustration, the fluid described herein will be a dielectric or insulating liquid.

The generator 10 includes a motor 12 for driving a pump 14 which forces a dielectric liquid 16 into a high voltage generator section 18. In the generator section 18, the liquid 16 is subjected to a strong electric field in an ionizer 20 where ions of a given sign (such as negative) are produced in the liquid 16. The ions flow with the liquid 16 into a conduit such as a tapered ion transport passageway 22 and form a space charge which advances to an ion collector 24. A high voltage output or emitter electrode 26 at the ion collector 24 is designed to collect significantly fewer ions than that collected by the ion collector 24 and becomes positively charged relative to the charge on the ion collector 24 and that on a flat plate electrode 28 which is provided with a narrow slot 30 and which is electrically connected to the ion collector 24.

The relative charge on the emitter electrode 26 and the ion collector 24 induces an electric field therebetween, which produces ions having an opposite (such as positive) sign from that of the given sign. The negative ions which are not collected are neutralized by the positive ions and the excess positive ions are urged by the flow of the liquid 16 into the next ion transport passageway 32. A high voltage output terminal 34 is connected to the emitter 26. The ionization, ion collection and ionization process is repeated as the liquid 16 flows through the tortuous path formed by the series of ion transport passageways 22, 32, etc., so that a high voltage, such as more than 500,000 volts, is applied to the output terminal 34. It is observed that the ionization is achieved by the electrodes 26 and 28 without the connection thereof to an independent power supply.

Considering FIGS. 1 and 2 in detail, the pump 14 may be a centrifugal type pump capable of operation at a range of 10 to 100 p.s.i. at liquid flow rates of 10 to 500 gpm, depending upon the pressure drop across the generator section 18 and the desired liquid flow rates in the ionizers. The pump 14 forces the liquid 16 into an input conduit 42 which is connected to an input port 44 of the generator section 18. The generator section 18 is fabricated from electrically insulating material which is slightly electrically conductive at the electric potentials which exist in the ion transport passageways. The materials paper phenolic, linen phenolic, slightly electrically conductive carbon filled epoxy material, and a material sold under the trade name "Benelex 70" by the Masonite Company, have been used successfully. These materials have resistivity in the range of $10^{-10}$ to $10^{-12}$ ohm cm. The materials have been suitable for use, for example, when transformer oil is used as the liquid 16. These materials provide a low leakage current flow to a metal shield 46 surrounding the generator section 18. Such flow prevents a high charge from building up on the walls 38 of the ion transport passageway 22 as a result of ion diffusion to the walls. When such a charge builds up, breakdown occurs relatively easily along the walls 38 and significantly reduces the breakdown voltage between the collector 24 and the ionizer 20. With the slightly conductive material, the breakdown voltage is limited only by that of the dielectric liquid 16. Thus, the generator section 18 may be fabricated from such materials having a resistance which is low enough to remove excess charges deposited on the passageway surfaces and at the same time a resistance which is high enough as not to remove more than a fraction, such as 5—10 percent of the current which is delivered to the electrode 34.

More particularly, the slightly electrically conductive material is effective to insulate against electrical breakdown through or along the walls 38 of the ion transport passageway 22 which enclose the space charge formed by the ions moving toward the ion collector 24. In the design of the generator section 18, the space charge density ($q$), the ion mobility ($b$) and the breakdown potential ($E_{b-l}$) are primary design factors which are known once such factors as liquid flow rate and the specific liquid 16 are determined. Thus, a breakdown factor ($F_b$), where $F_b = (E_{b-l}) \cdot (q) \cdot (b)$, is known. Applicants have determined the breakdown factor ($F_b$) must be less than or equal to an insulating factor ($F_i$) of the material used to fabricate the walls 38. The insulating factor ($F_i$) is equal to the product of the electrical breakdown potential ($E_{b-i}$) of the insulating material and the conductivity of the material ($c$). When this is the case, the slightly electrically conductive material will conduct current at an electrical potential which is lower than the breakdown potential of such material. Thus, the ions which diffuse to the walls 38 will be ineffective to build up a potential sufficient to cause breakdown along or through the walls 38. Rather, the only breakdown which will occur should the voltage not be controlled will be in the fluid 16, which is not destructive to the walls 38.

The liquid 16 for this design has a viscosity in the range of .8 to 1.2 poise. It has been found that transformer oil, such as sold as Type 10c by the General Electric Company, is as satisfactory for use as the dielectric liquid 16. With such a relatively high viscosity, the space current which can be delivered at the end of the ion transport tube 22 away from the ionizer 20 may be as high as 80 percent of the initial space charge density at the entrance to the ion transport passageway 22.

The ionizer 20 is provided in a generally rectangular cross section portion 52 of the inlet port 44. The ionizer 20 includes an emitter electrode 54 which may be in the form of a point or points, and which is shown in the drawings in the general configuration of an injector razor blade. The emitter electrode 54 is mounted on a conductive support 56 which is secured to a wall 58 of the portion 52. The support 56 is electrically connected to an electrical conduit such as a wire 60 connected to ground. The emitter electrode operates in conjunction with a flat collector electrode 62 which may be in the form of a flat plate 64 provided with a suitable slot 66 and an aperture 68 to permit passage of the liquid 16 therethrough. By providing narrow slots in the plate opposite to elongated, bladelike emitter electrodes, applicants do not provide any locations at which the electric field tends to concentrate. In this manner, applicants avoid serious reduction in the breakdown voltage and do not limit the voltage which can be built up at the ion collector.

In a specific embodiment of the ionizer 20, the emitter electrode 54 may be fabricated from an injector-type razor blade, such as a stainless steel, single-edge injector-type razor blade sold by the Schick Company. Such a blade has a length in the direction of fluid flow (as viewed in FIG. 1) of 8 mm., a width of 37 mm., and a thickness of .26 mm. In such embodiment, the flat collector electrode 62 is provided with a slot 66 which is opposite to the tip 78. The slot may provide a 1 mm. by 37 mm. opening through which the fluid 16 may pass. The tip 78 is located .8—1.2 mm. away from the side of the collector electrode 62 nearest the emitter electrode 54.

The collector electrode 62 is connected to a conductor 72 which is connected to a power supply 74 across a current limiting resistor 76 and a control switch 77. The power supply 74 provides a high voltage, such as 15—20 $kV$ across the emitter and collector electrodes 54 and 62, respectively, for establishing a very high electric field adjacent to the tip 78 of the emitter electrode. As the liquid 16 flows past the emitter electrode 54, the high electric field ionizes the liquid and produces negative ions, for example, so that a space charge is developed. The pump 14 is adjusted to provide a given liquid flow velocity, such as 20 meters per second, through the slot 66. The ions attempt to flow to the collector electrode 62, but with the given flow velocity through the slot, sufficient ions are flushed into the ion transport passageway 22 to develop an initial space charge density of 0.1 coulombs per cubic meter, for example, in the passageway. Under conditions such as these, less than a 1.0 microampere current flows from the tip 78 to the collector 62, thus, the power supply 74 need only supply a low output current and relatively low electrical input into the generator 10.

The space charge flushed into the ion transport passageway 22 is advanced by the flowing liquid 16 into the ion collector 24. In the embodiment shown in FIGS. 1 and 2, the ion transport passageway 22 is provided with a generally rectangular cross section which commences adjacent to the slot 66 in the flat electrode 62. The passageway 22 defines a channel or flow path for the liquid 16. The opposite walls 38 of the passageway 22 taper outwardly, whereas sidewalls 82 (FIG. 2) thereof are parallel. Clearly, tapering walls of the passageway 22 can be provided by other cross-sectional configurations to compensate for the fact that the space charge density decreases as the downstream distance from the ionizer 20 toward the ion collector 24 increases. In this manner, the net space charge in any given cross section of the passageway 22 is approximately the same as the net space charge in an adjacent cross section of the adjacent passageway 32. Accordingly, there is essentially no net radial field transverse to the direction of the fluid flow in the passageways 22 and 32. In addition, the tapering of the walls 38 provides a diffuser section which reduces the pressure drop as the liquid flows in the passageway 22 to provide a concentration of pressure drop where the liquid enters the ion collector 24.

The ions which are lost as the space charge advances to the ion collector 24 advance to the walls 38 of the passageway 22. Because the walls are slightly conductive, a charge does not build up on the walls. Rather, a small current is conducted therethrough to the metal shield 46 so that no breakdown of the walls 38 occurs. In this manner, the voltage developed across the length of passageway 22, for example, will be limited only by the voltage that will cause the liquid 16 to break down.

The ions which are not lost during the transit in the ion transport passageway 22 to the ion collector 24, pass through an aperture 82 in the flat plate electrode 28 and enter the ion collector 24. The ion collector 24 can be fabricated from separate parts or can be made in one unit as a single insert, for example. The ion collector 24 includes the metal, flat plate electrode 28 which is connected to a metal collector 84 having a plurality of sections 85 provided with generally semicircular cross sections and extending along the same width as the passageway 22. A metal portion 86 is provided on the flat electrode 28 within each section 85 for guiding the flow of the liquid 16 from a generally upward direction as it flows through the aperture 82 to a generally downward direction (as viewed in FIG. 1) where the liquid passes the emitter electrode 26 and then flows through the slot 30 in the electrode 28. The metal collector 84, including the portion 86 and electrode 28, are electrically interconnected and are insulated from the emitter electrode 26 and the remainder of the generator by the slightly electrically conductive material which forms the housing of the generator section 18. The emitter electrode 26 may have the same detailed construction as the emitter electrode 62 of the ionizer 20. Similarly, the spacing of the electrode 28 and the dimensions of the slot 30 thereof may be the same as in the ionizer 20. By making the emitter electrode 26 of small area and size, the internal electrical capacitance of the generator unit 10 is small.

In the operation of the ion collector 24, the ions entering the aperture 82 diffuse onto the surfaces of the collector 84, the portion 86 and the flat electrode 28 which are exposed to the liquid 16. For ease of description, the surfaces of these elements 84, 86 and 28 which are exposed to the liquid 16 will be referred to as the main ion collector surfaces, whereas the surfaces of the emitter electrode 26 which are exposed to the liquid 16 will be referred to as secondary ion collector surfaces. Because the main ion collector surfaces have many times more area than the secondary ion collector surfaces, the main surfaces collect ions at a much higher rate than the secondary surfaces. If the ions entering the ion collector 24 are negatively charged, then the secondary surfaces will be charged less negatively, hence positively relative to the high negative charge on the main surfaces. As the difference in the charge on the main and secondary surfaces increases, a high electric field is developed so that the fluid in a volume 98 adjacent to the tip 96 is ionized to create a space charge having opposite (positive) sign with respect to that of the space charge in the passageway 22. The space charge is flushed out of the volume 98 of the ion collector 24 and into the next subsequent ion transport passageway 32 where the operation described above with respect to the passageway 22 is repeated. The adjacent passageways 22 and 32 form counterflow paths for the liquid 16 and for purposes of description, can be considered as one counterflow unit.

In the operation of the ion collector 24, the rate of diffusion of negative ions to the main ion collector surfaces is in equilibrium with the rate at which the positive ions are conducted from the tip 96 to the flat electrode 28. Accordingly, the voltage on the main ion collector surfaces with respect to the tip 96 will stay constant, and the number of negative ions collected by the main ion collector surfaces is proportional to the number of space charges entering the aperture 82 and the percent of positive ions flowing through the slot 30.

The walls 102 of the passageway 32 are tapered and diverge with increasing distance from the plate electrode 28 to the aperture 68 in the electrode 62. This tapering provides a constant number of ions per unit of length of the passageway even though the space charge density decreases with fluid flow away from the electrode 28. The main ion collector surfaces and secondary ion collector surfaces are proportioned so that approximately the same space charge density is developed at the start of the passageway 32 as is developed at the start of the passageway 22. Thus, at adjacent cross sections of the passageways 22 and 32, the net radial field will be near zero.

As shown in FIG. 1, an ion collector 112 similar to the ion collector 24 is provided at the end of the passageway 32 for collecting the positive ions which pass through the electrode 68 and negatively ionizing the fluid 16 which enters a next subsequent ion transport passageway 114. The cycle of collecting ions and reionizing the liquid 16 is repeated as the liquid flows through successive ion transport passageways 116, 118, and 120 and sections 85 and 122 of the ion collectors 24 and 112, respectively. The liquid 16 may be neutralized by an ionizer (not shown) provided at the end of the passageway 120 prior to entrance into a return conduit 124 which supplies the liquid 16 to the pump 14.

The high voltage generator 10 may be operated independently of any external power source by opening the switch 77 after initial operation so that the power supply 74 is not connected to the electrode 62. In this independent mode of operation, the electrode 62 attains a floating potential as hereinafter described. The electrode 62 of the ionizer 20 is maintained at a positive potential (relative to the electrode 54) by the power supply 74 so that negative ions are generated and flow through the slot 66 into the ion transport passageway 22. The negative ions are collected and positive ions are formed in the ion collector 24. The positive ions are flushed into the passageway 32 and are collected on main ion collector surfaces 113 of the ion collector 112. The potential on the surface 113 of the collector 112 rises until it reaches approximately the same potential as is applied by the power supply to the electrode 62. Because the ion collector 112 is electrically connected to the electrode 62, the power supply 74 can be disconnected by opening the switch 77 to initiate the independent mode of operation.

The supply of positive ions to the surfaces 113 of the ion collector 112 is maintained as a result of current flow to the terminal 34. If the terminal 34 is open, for example, the high voltage on the terminal 34 will induce a displacement current to the terminal 34. The displacement current will be conducted to the electrode 26 to permit generation of positive ions which are flushed into the passageway 32 for collection on the surface 113 of the ion collector 112. The positive ions will maintain the electrode 62 at the potential required to negatively ionize the fluid 16 flowing into the passageway 22 and maintains a high relative potential across an emitter electrode 115 of the ion collector 112 to permit negative ionization of the fluid entering the passageway 114.

The generator 10 provides a high negative voltage at the high voltage terminal 34 by initially imposing a negative potential on the emitter electrode 54 in the ionizer 20. The generator 10 will perform equally well as a generator of a high positive voltage by impressing a positive potential on the emitter electrode 54 instead of the negative potential.

Referring now to FIG. 3, a number of generator units are shown having the high voltage output terminals 34 thereof connected in parallel to a high voltage power line 140 which is connected to a load 150. In this manner, the generators 10 of the present invention may be used to provide higher current capacity than that available from one generator.

Referring to FIG. 4, there is shown a number of generator units 10 having the high voltage terminals thereof connected in series with a load 151. Stabilizing loads 152 are connected to the terminals 34.

It is to be understood that the above-described arrangements are simply illustrative of the application of the principles of this invention. Numerous other arrangements may be readily devised by those skilled in the art which will embody the principles of the invention and fall within the spirit and scope thereof.

I claim:

1. In a high voltage generator in which ionizer means charges a charge transport fluid and wherein electrode means collects the charge from said charged fluid for generating the high voltage, the improvement which comprises:

housing means defining a passageway for guiding said charge transport fluid from said ionizer means to said electrode means, at least one wall of said passageway being fabricated from relatively conductive, electrically insulating material having an electrical resistance sufficiently low to effectively remove excess charges deposited on its surface from the transport fluid and at the same time sufficiently high as not to remove more than a fraction of the electrical current delivered to the high voltage electrode; and

conductive means in electrical contact with at least a portion of said wall opposite said passageway, said conductive means being adapted to remove said excess charges through said material.

2. A high voltage generator according to claim 1, in which said material is taken from the group consisting of paper phenolic, linen phenolic and carbon-filled epoxy.

3. A high voltage generator in accordance with claim 1 in which said material also has an electric resistivity in the range of $10^{-10}$ to $10^{-12}$ ohm centimeters.

4. A high voltage generator in accordance with claim 1 in which:

pairs of ionizer means and collector means are arranged in seriatim;

one of said passageways is provided between said ionizer means and said collector means of each said pair, said housing means being constructed with a partition to provide said passageways adjacent to each other and arranged to guide said fluid in generally parallel paths; and

said housing means and said partition being constructed to taper the wall of each of said passageway so that the volume per unit length enclosed by each said passageway increases in the direction of fluid flow.

5. A high voltage generator in accordance with claim 1 in which at least a portion of said partition providing said adjacent passageways is fabricated from a slightly electrically conductive material having an electric resistivity in the range of $10^{-10}$ to $10^{-12}$ ohm centimeters so that charges of opposite sign collected on opposite sides of said partition are neutralized to preclude the buildup of a high potential on the walls of said passageway.

6. A high voltage generator operating under the principle that an insulating fluid passing through a generally parallel, electric field produced by a with sections element will assume a charge of a given sign, which comprises:
conduit means having passageways for guiding said fluid along multiple flow paths wherein said flow paths are generally parallel, said conduit means being provided with sections interconnecting said flow paths, each of said sections having an entrance port and an exit port;
ionizer means for producing ions of said given sign in said fluid in a first of said flow paths;
means for pumping said insulating fluid through said passageways and said sections;
conductive means received in each of said sections, said conductive means having a given surface area exposed to said fluid for collecting said ions from said fluid;
output electrode means received in each of said sections, said electrode means being electrically insulated from said conductive means, said electrode means having a sharp element and a small surface area exposed to the fluid relative to said given surface area so that said output electrode means collects fewer ions from said fluid than said conductive means, said output electrode means assuming a charge that is substantially less than the charge on said conductive means; and
a plate electrode electrically connected to each of said conductive means, each said plate electrode having an opening therein adjacent to said sharp edge of one of said output electrode means for inducing an electric field between said sharp element and said plate electrode and for directing the flow of said fluid through said field to produce ions in said fluid having a sign opposite to said given sign.

7. A high voltage generator which comprises:
conduit means having a passageway therein for defining a flow path wherein adjacent first and second sections of said passageway are generally parallel;
means for pumping an insulating fluid through said conduit means;
ionizer means received in a first of said sections for producing ions having a given sign in said fluid flowing through said first section;
means interposed between said first section and said second section of said passageway for collecting said ions from said fluid, said collecting means including a flat electrode having a slot therein for directing said fluid into said second section; and
a high voltage output electrode having a first sharp element positioned adjacent to said slot, said output electrode being effective to collect fewer ions than said collecting means so that an electric field is impressed across said flat electrode and said output electrode to produce ions of a sign opposite to said given sign in said fluid entering said second section.

8. A high voltage generator according to claim 7, wherein:
said fluid flows in opposite directions in said adjacent first and second sections; and
at least one wall of said first and second sections is tapered to provide a cross section area in each passageway which increases in the direction of fluid flow, said taper of said sections being effective to maintain in said passageway a relatively constant ion content per unit length of said passageway.

9. A high voltage generator in accordance with claim 7, wherein:
said passageway is tortious for forming a plurality of each of said first and second sections;
second means are mounted between successive ones of said second and first sections for collecting said opposite polarity ions from each of said second sections, said second means including a second flat electrode having a second slot therein for directing said fluid into the next successive first section;
a first emitter electrode having a second sharp element is mounted adjacent to said second slot, said first emitter electrode being effective to collect fewer ions than said second collector means so that an electric field is impressed across said flat electrode and said first emitter electrode to produce ions of said given sign in said fluid entering said next successive first section;
said ionizer means includes a power supply, a second emitter electrode having a third sharp element and being electrically connected to said first emitter electrode, and a third flat electrode having a slot therein adjacent to said third sharp element, said third flat electrode being electrically connected to said second collecting means; and
switch means for selectively connecting said power supply to said third flat electrode to initiate ionization of said fluid, said switch means being open subsequent to the initial operation of said apparatus to permit operation of said generator independently of said power supply.

10. A high voltage generator in accordance with claim 7, which further comprises a pair of high voltage generators in accordance with claim 8, the high voltage output electrodes of said pair of generators being connected in parallel to provide high output current characteristics.

11. A high voltage generator in accordance with claim 7, which further comprises a pair of high voltage generators in accordance with claim 8, the high voltage output electrodes of said pair of generators being connected in series to provide higher voltage output characteristics.

12. A high voltage generator which comprises:
housing means defining a passageway for insulating fluid, said passageway comprising a series of counterflow units, each counterflow unit comprising a first diverging channel for conducting said fluid in a first direction and a second diverging channel generally parallel to said first channel for conducting said fluid in a second direction opposite to said first direction;
means for pumping said fluid through said passageway;
a first electrically conductive insert which includes; a first flat electrode section having a first slot therein to permit passage of said fluid from said pumping means into said first channel of a first of said units and a first generally U-shaped section having one end thereof open for receiving said fluid from each said second channel of said units and having a second flat electrode at the other end thereof, said second flat electrode section having a second slot therein to permit the flow of fluid into the first channel of the next successive counterflow unit, and a plurality of electrically interconnected emitter electrodes having a sharp edges thereon, one of said electrodes being mounted adjacent to said slot of each said second flat electrodes, said emitter electrodes being electrically insulated from said first insert; a high voltage power supply; switch means for selectively connecting said power supply to said first insert to produce in said fluid ions of a given sign;
a second electrically conductive insert which includes; a second generally U-shaped section for each of said units, each said second section having an opening at one end for receiving said fluid from said first channels of said units;
a third flat electrode closing the other end of each of said second U-shaped sections, each said third flat electrode having a third slot therein to permit the flow of fluid into said second channels of each of said units; and
a high voltage output electrode for each of said third flat electrodes, each output electrode being electrically insu-

lated from said first and second inserts, each of said output electrodes having a sharp element thereon mounted adjacent to one of said third slots of said third flat electrodes;

the area of said second section in contact with said fluid having said given sign being substantially greater than the area of said output electrodes in contact with said corresponding fluid so that an electric field is produced across said output electrodes and said third flat electrodes to produce ions in said fluid in said second channels of a sign opposite to said given sign;

the area of said first U-shaped section in contact with said fluid having said sign opposite to said given sign being substantially greater than the area of said emitter electrode so that upon disconnection of said power supply from said emitter electrodes an electrical field is produced across said emitter electrodes and said second flat electrode sections to produce ions of said given sign in said fluid in said first channels of said units.

13. A high voltage generator according to claim 12, in which:

each of said first diverging channels is provided with an entrance port which conforms to said first slot and an exit port which conforms to said open end of said first U-shaped section; and

said flat electrodes being mounted substantially perpendicular to said direction of fluid flow through said respective first and second channels.