Feb. 12, 1957 N. FELICI 2,781,460

ELECTROSTATIC MACHINE WITH CONVEYOR OF INSULATING MATERIAL

Filed March 7, 1955 2 Sheets-Sheet 1

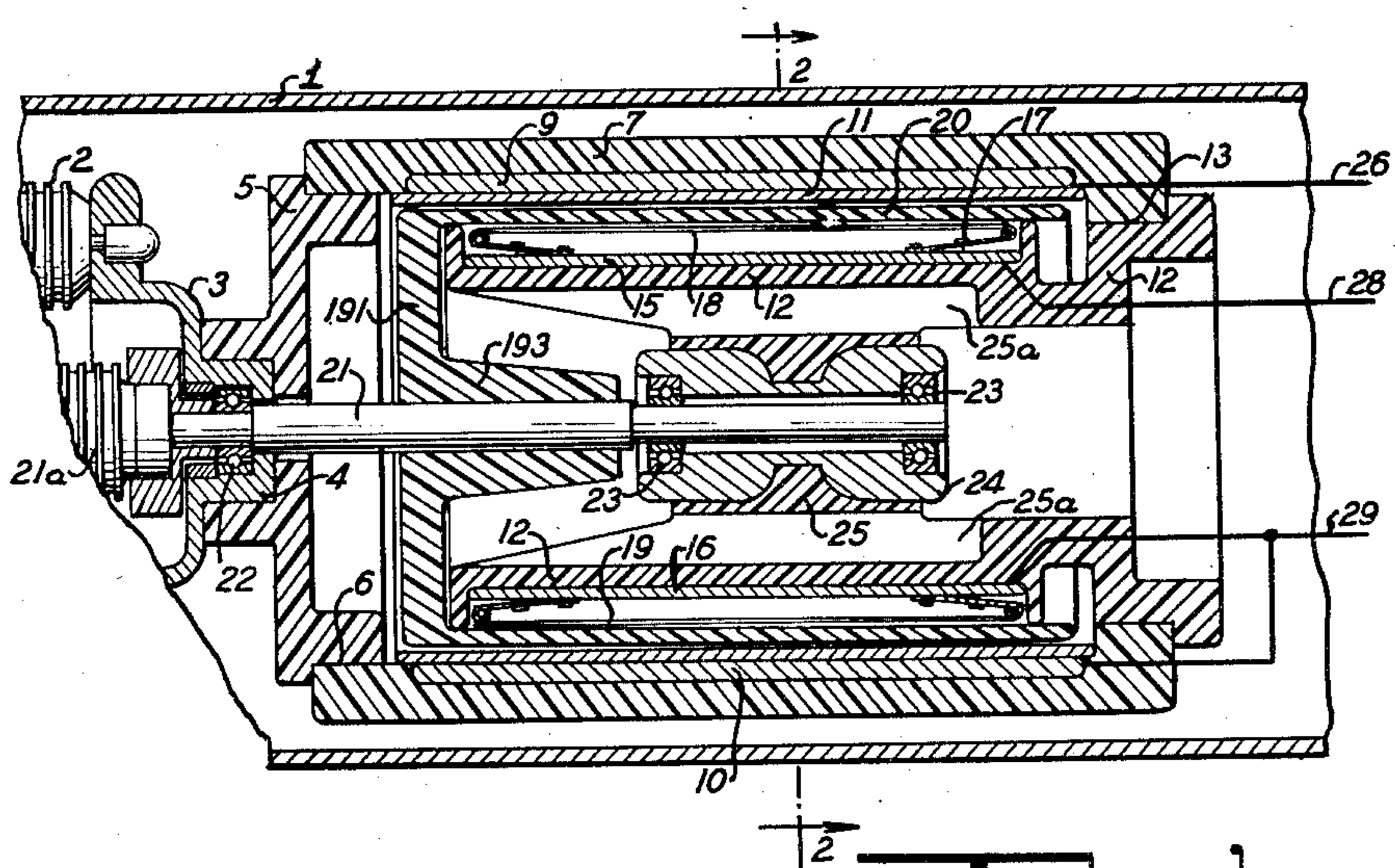

Fig. 1

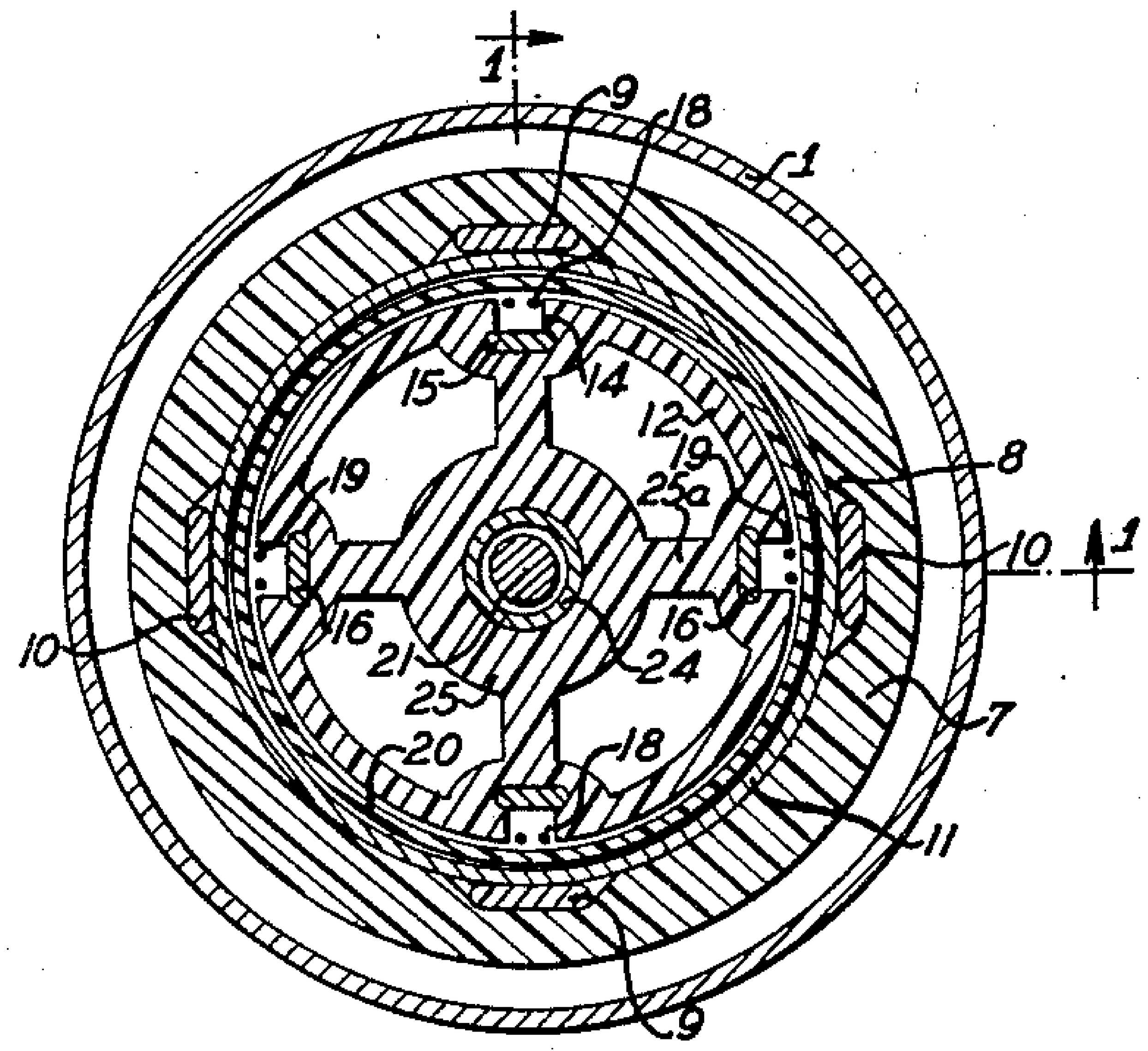

Fig. 2

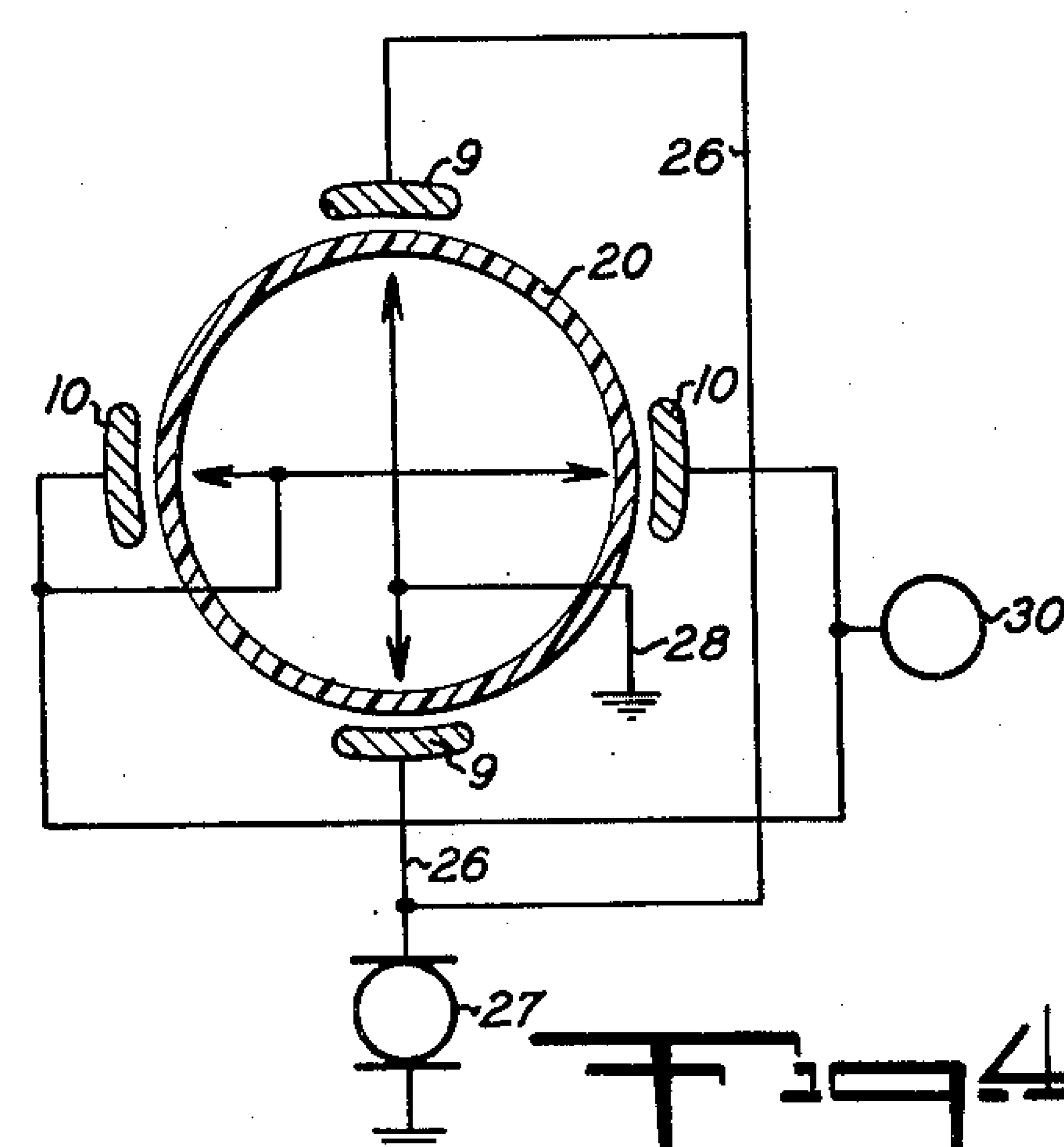

Fig. 4

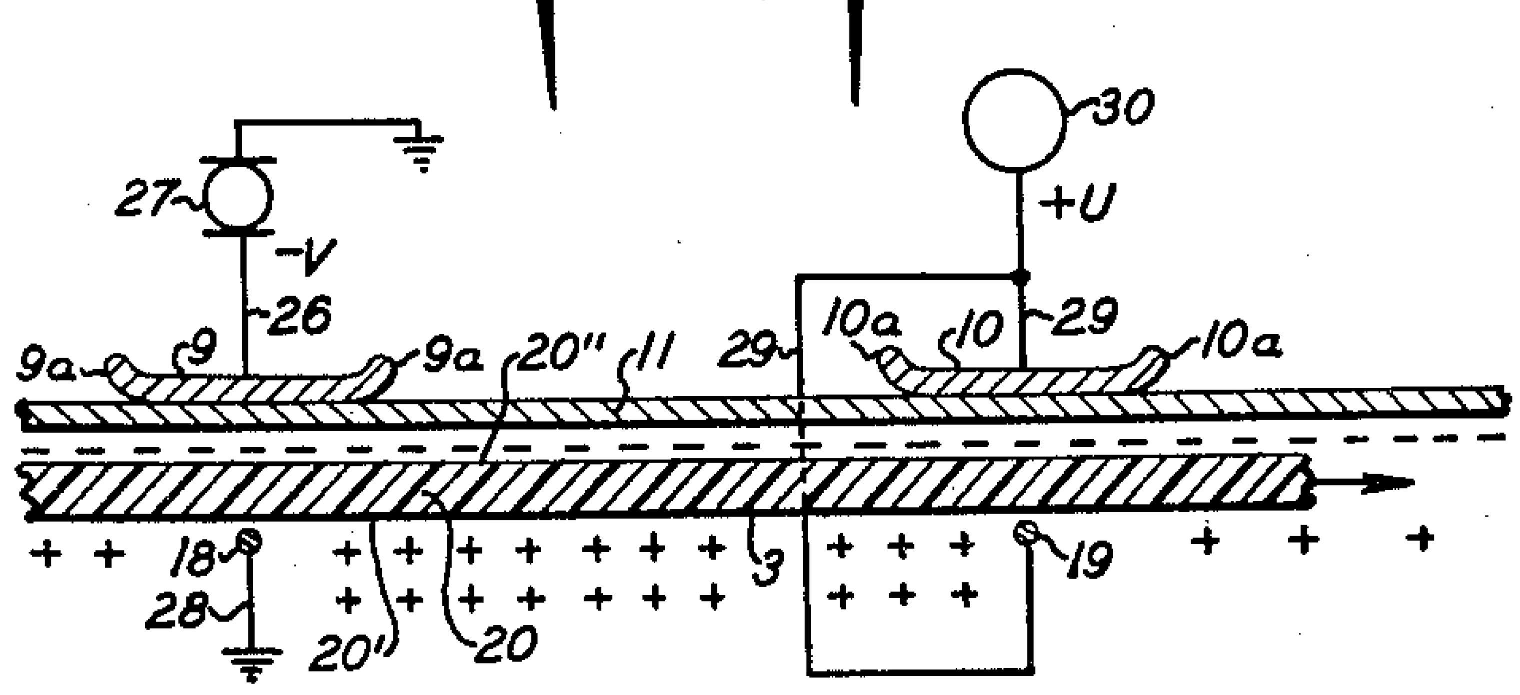

Fig. 3

INVENTOR

NOEL FELICI

BY George H. Corey

ATTORNEY

Feb. 12, 1957 N. FELICI 2,781,460

ELECTROSTATIC MACHINE WITH CONVEYOR OF INSULATING MATERIAL

Filed March 7, 1955 2 Sheets-Sheet 2

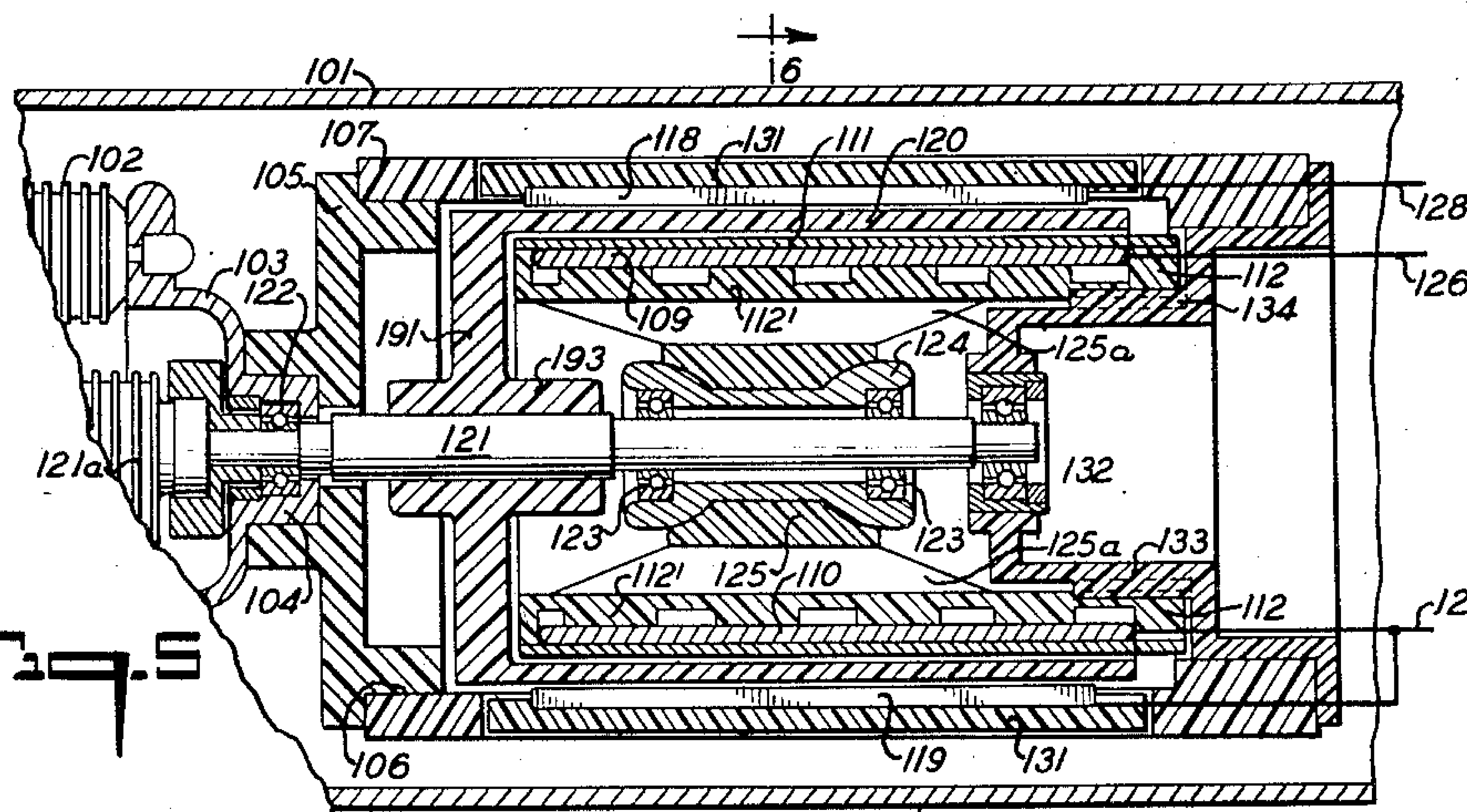

Fig. 5

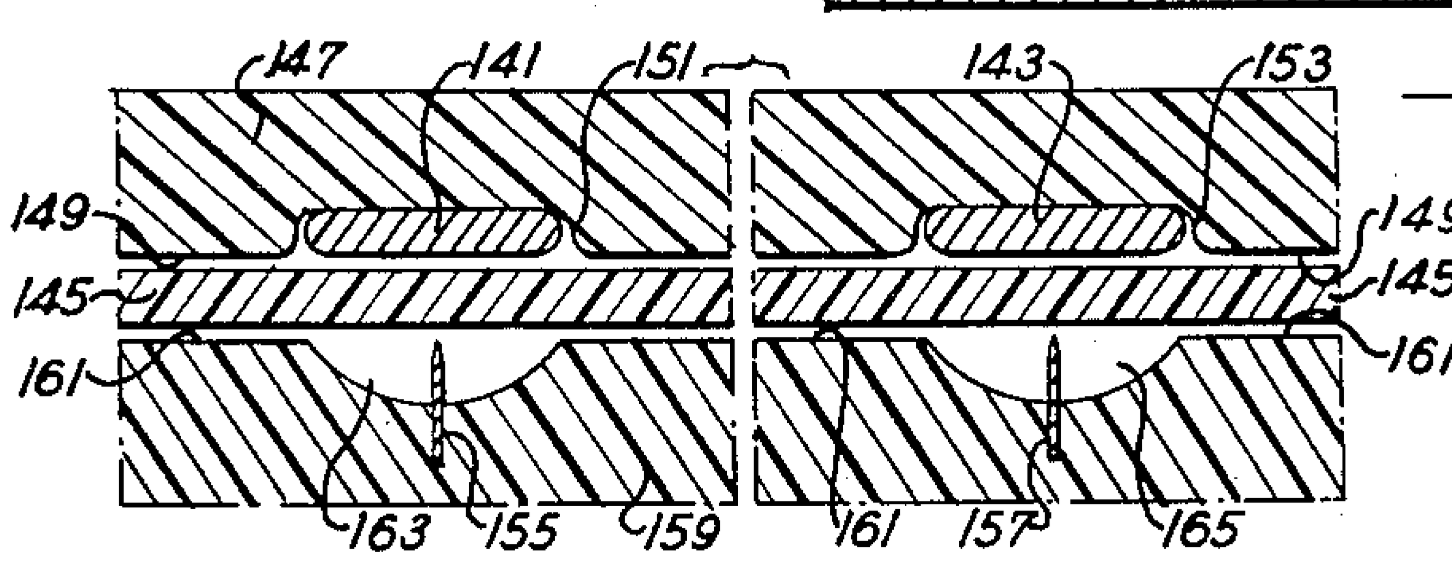

Fig. 7

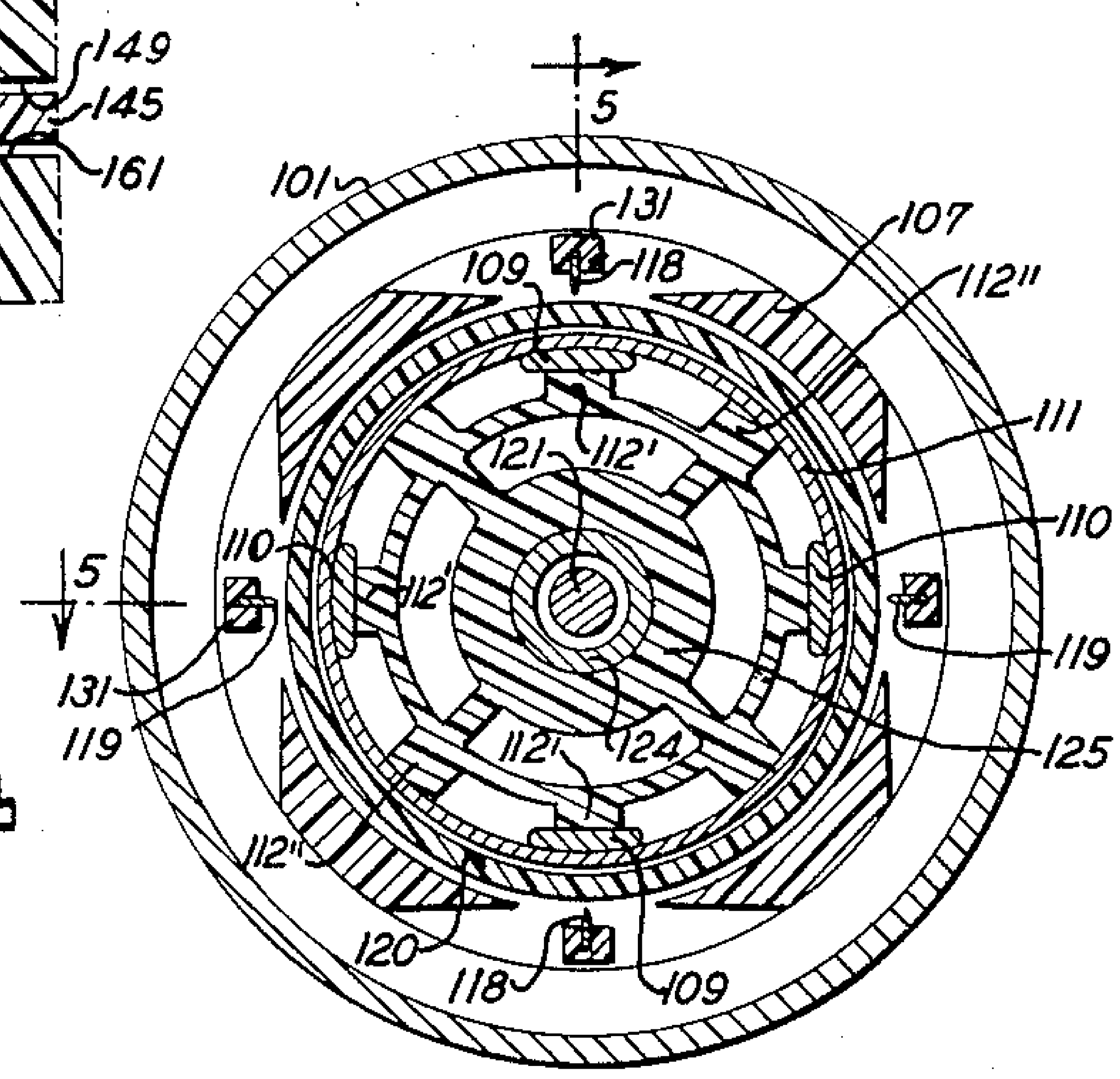

Fig. 6

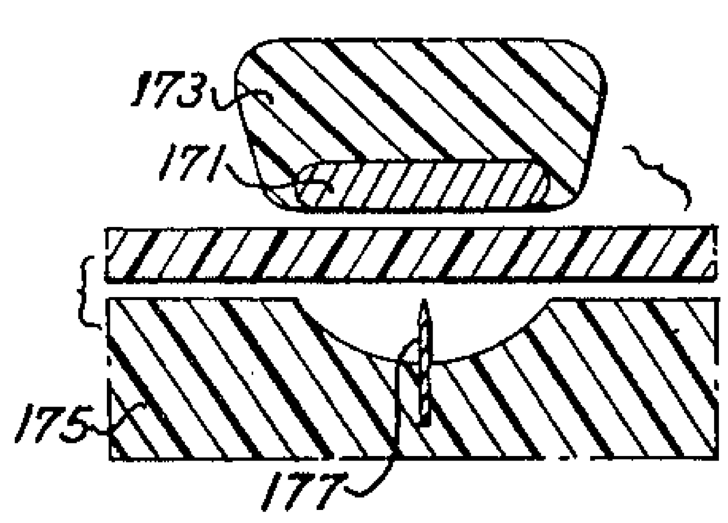

Fig. 8

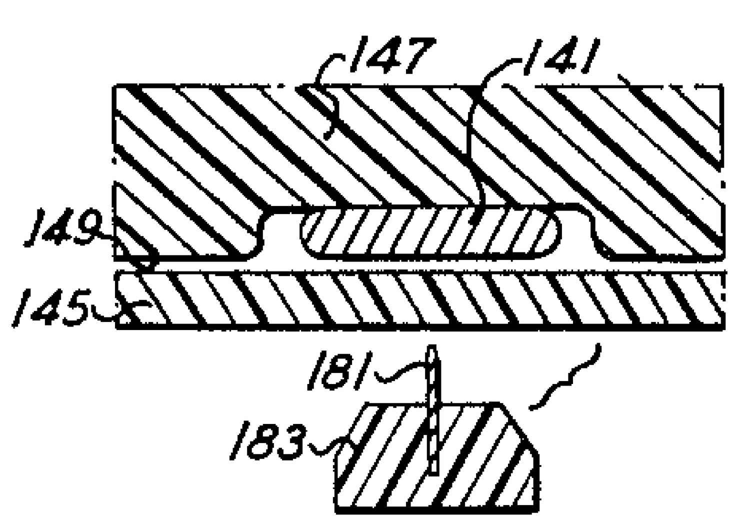

Fig. 9

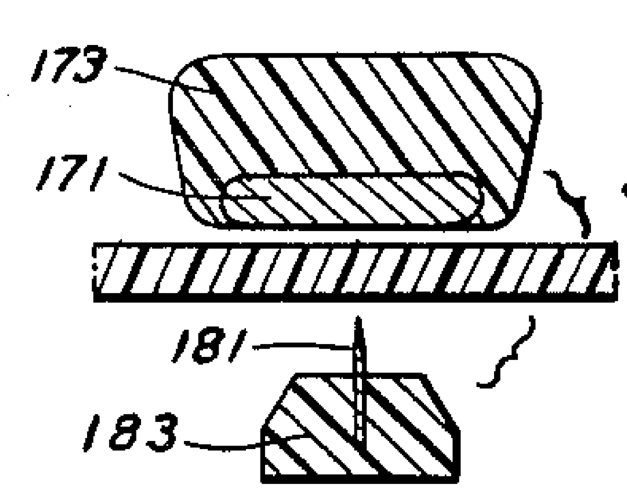

Fig. 11

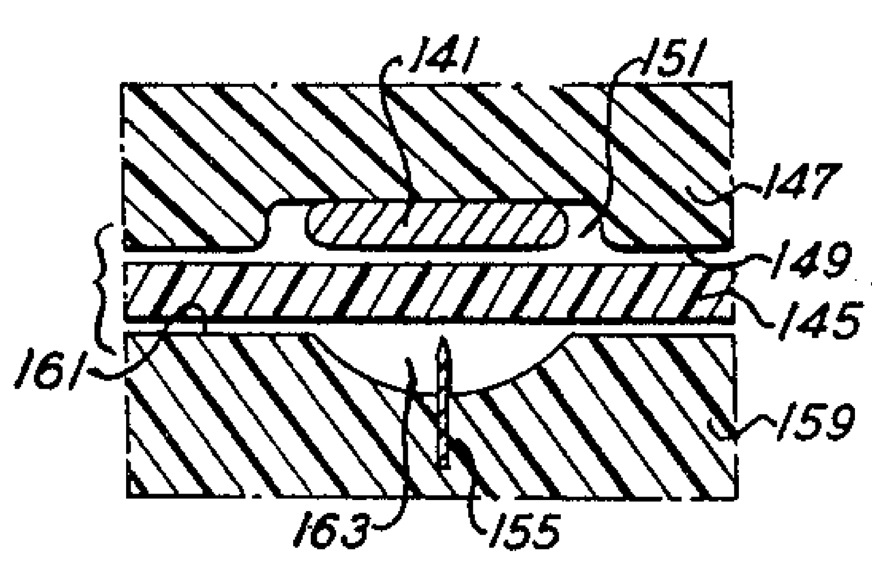

Fig. 10

INVENTOR

NOEL FELICI

BY George H. Corey

ATTORNEY

United States Patent Office

2,781,460

Patented Feb. 12, 1957

2,781,460

ELECTROSTATIC MACHINE WITH CONVEYOR OF INSULATING MATERIAL

Noel Felici, Grenoble, France

Application March 7, 1955, Serial No. 492,491

Claims priority, application France November 21, 1951

30 Claims. (Cl. 310—6)

The present invention relates to electrostatic machines constructed with a conveyor member for conveying the electrostatic charges, this conveyor member being made of an insulating material and being rotatably or otherwise mounted for relative movement with respect to conductive electrodes. The conveyor and electrodes are disposed in a medium having a high dielectric strength, such as a pressurized gas, the electric charges being first deposited on the conveyor by an element which causes ionization of the dielectric medium and thereafter being collected by a charge collecting element for delivery to the machine terminal.

A number of such machines have been proposed and some have been constructed heretofore but their low power and poor efficiency have not been favorable to their industrial utilization.

An object of the present invention is to provide an electrostatic machine of the above type having a high power per unit of volume and weight and to this end the invention preferably provides a cylindrical arrangement of rotatable and fixed parts.

Another object of the invention is to provide an electrostatic machine which is simple to build and consequently of low cost.

Still another object of the invention is to provide an electrostatic machine dispensing with frictional contact of conductive parts, such as contact between brushes and collectors, which are subject to wear and which cause the production of conductive dust which may lead to leakage currents or to short circuits.

A further object of the invention is to provide machines of the above mentioned type in which a high voltage, that is, a large increase in potential of the charges carried by the conveyor, may be secured in the movement of this conveyor between the position in which the charges are deposited thereon and the position in which the charges are collected from the conveyor and delivered to a terminal of the machine.

A still further object of the invention is to provide in a machine of the type referred to for a considerable reduction of losses due to friction of the members moving in a dielectric fluid and due to turbulence developed in this fluid.

In order to achieve these objects an electrostatic machine according to the invention comprises fundamentally at least one conveyor member of insulating or dielectric material capable of withstanding a high electric flux density, this conveyor having two parallel faces providing even, regular surfaces and being supported in relation to a conductive electrode for movement of one relative to the other in the direction parallel to the faces of the conveyor. The conveyor is of such form and disposition that successive adjacent portions thereof are moved into and out of face to face relation to each electrode in succession of at least a pair of electrodes disposed at the same face of the conveyor. Each of the electrodes of the pair has a surface substantially parallel with the faces of the conveyor when in face to face relation thereto, each electrode also having a substantial extent of this surface perpendicular to the direction of relative movement of the conveyor and the electrode with respect to each other. One of the electrodes of the pair which may be called the input inductor electrode is electrically connected to a terminal of an auxiliary source of direct current voltage while the other electrode of the pair which may be called the screen or the output inductor electrode is connected with a terminal of the machine which will be referred to as the output terminal. The other terminal of the auxiliary source is connected to the input terminal of the machine.

Cooperating with the conveyor and the electrodes are two ionizing elements which act to ionize the dielectric fluid. One of these ionizing elements will be referred to as the input ionizer and serves to deposit the charges on the conveyor surface. The other ionizing element acts as a collector of the electric charges conveyed by the conveyor. These ionizers are formed as thin elongated members extending perpendicular to the direction of relative movement of the conveyor and the inductor electrodes. They are disposed at the opposite face of the conveyor from the inductor electrodes and parallel to this other face and as close as possible thereto. The input ionizer and the output ionizer respectively are also disposed opposite the input and output inductor electrodes. The input and output ionizers respectively are connected to the input and output terminals of the machine.

The difference of potential which is maintained between the input ionizer and the input inductor by the above mentioned auxiliary source develops an electric field in the space between the ionizer and the conveyor. It will be understood that the conveyor is moved in the direction generally transverse to the lines of force of the electric field. The extent of the conveyor is continuous in the direction of the relative movement thereof with respect to the electrodes and its active surfaces are continuously moved through this field. The input ionization element is of such form that the surface thereof facing the conveyor is restricted and a high concentration of the electric field thereon is produced. The gaseous dielectric medium in which this input ionizer and the conveyor are disposed is ionized along the length of this ionizer in the space between the ionizer and the adjacent surface of the conveyor member. The ionization which thus takes place causes ions carrying electric charges to migrate to the adjacent face of the conveyor upon which these ions are carried forward in the movement of the conveyor relative to the electrodes toward the position of the output inductor electrode which is disposed in spaced relation to the input inductor electrode along the conveyor surface. The output ionizer collects the charges which are then conducted to the output terminal of the machine through a suitable inductor.

The ionizers both provide a surface of small radius facing the conveyor, such as may be provided by wires or preferably by thin blades disposed edgewise to the face of the conveyor. These wires or blades have their length extending transversely of the direction of relative movement of the conveyor with respect to the inductor electrodes. The ionizers both are disposed as close as possible to the adjacent face of the conveyor while avoiding contact therewith. In the relative movement of the conveyor and the ionizers the potential of the charges carried by the ions which are transported by the conveyor at its surface is increased from the potential at the input ionizer to the potential of the output terminal.

It is a feature of the invention that at the face of the conveyor at which the inductor electrodes are disposed and in closely spaced relation to this face of the conveyor a body is disposed extending between the two inductor electrodes and in contact therewith. The material of which this body is made must have a sufficiently high resistivity to prevent undue leakage current flowing between the two inductor electrodes, these inductors as above stated being at different potentials. A material having a resistivity of not substantially less than 10^{10} ohms per cm. per cm.^{2} serves to control the gradient of the potential difference between these electrodes, that is, the tangential field along the surface of the conveyor.

In one aspect in accordance with this feature of the invention a homogeneous slightly conductive material, for example, one having a resistivity substantially in the range between 10^{10} and 10^{13} ohms per cm. per cm.^{2} may be used which will allow a slight flow of current to take place between the two inductor electrodes which will make it possible to control the gradient of potential between the two inductor electrodes.

Taking into account the potential difference to be established in a particular case between the two inductor electrodes, the resistivity of the material of the interposed body and the thickness thereof perpendicular to the face of the conveyor may be selected so that a smooth gradient of potential in the direction generally parallel to the movement of the conveyor may be secured. A substantially constant gradient may be secured in this manner, if desired, by suitable disposition and thickness of the material of this body.

This body of slightly conductive material should provide an even regular surface adjacent the conveyor surface. The thickness and disposition of the slightly conductive material in the region adjacent the conductive inductor electrodes may be such that there takes place in the zones which are adjacent the edges of the electrodes and which extend transversely of the conveyor movement a gradual rather than abrupt change of potential from the zone of constant potential at the one inductor electrode to the zone of potential varying along the slightly conductive material in the direction toward the other inductor electrode.

In another aspect of this feature of the invention relating to the control of the tangential field or gradient a material may be used for the body extending between the inductor electrodes which has a resistivity high enough to act as an insulating material, that is, a resisitivity not substantially less than 10^{14} ohms per cm. per cm.^{2}. Such a body also is formed with an even, regular surface adjacent the face of the conveyor and closely spaced in relation thereto. It is found that when such a body of insulating material is thus disposed extending between the inductor electrodes that a smooth gradient of potential is established extending between the zones of constant potential existing at the faces of the inductor electrodes when the space between the surface of the insulating material and the face of the conveyor is sufficiently reduced. It is believed that this action takes place by virtue of a layer of ions which accumulate on the surface of the insulating material which is in opposed relation to the face of the conveyor.

While it is usually preferable to use a slightly conductive material having a resistivity in the range 10^{10}–10^{13} ohms per cm. per cm.^{2}, in some cases an ordinary insulating material having resistivity not less than 10^{14} ohms per cm. per cm.^{2} may be used where such factors as cost, size and ease of fabrication to close dimensions are involved. Particularly in small machines satisfactory control of the potential gradient is secured without the difficulty and increased cost that are involved in providing the body of slightly conductive material.

As above indicated it is necessary that the space between the high resistivity body and the adjacent face of the conveyor shall be as small as possible limited by the necessity for mechanical clearance between the relatively moving parts. Especially where the conveyor is formed with a surface of revolution, such as a cylinder, and the body of high resistivity material also is so formed, close clearance may be secured. Moreover, the space or gap between the two surfaces may be made continuous and of uniform width along the conveyor surface in the direction of movement thereof. It has been found in a practical machine that the space or gap may be substantially in the range between .1 mm. and 1.5 mm. In general within this range the gap may be made larger for a machine having a conveyor of larger dimensions, for example, a large diameter of a cylindrical conveyor as compared with a machine having a conveyor of smaller diameter. It is preferable, having regard to the requirements for mechanical clearance between the relatively moving parts, that the gap be maintained as small as possible to secure the improvement in the tangential field.

In some embodiments in this feature of the invention the slightly conductive material may extend upon or cover and be in contact with the face of the inductor electrode that is disposed toward the conveyor face. The portion of the slightly conductive material covering the inductor face cooperates with the conductive body of the inductor electrode to form a composite inductor electrode structure. The body of slightly conductive material extending between the two electrodes for the purpose of controlling the tangential field or gradient of potential, as above described, may connect two such composite inductor electrodes. The body of slightly conductive material may be in the form of a continuous layer disposed in adjacent and closely spaced relation to the face of the conveyor and in contact with and covering the respective inductor electrodes and interposed between the respective inductor electrodes and the conveyor.

The portion of the slightly conductive material which covers the face of the inductor electrode serves to control or prevent discharge across the space between the inductor electrode and the conveyor. If for any reason ionization were initiated in the gap between the composite electrode and the conveyor, such ionization would result in a drop of the potential of the surface of the slightly conductive material because the high resistivity of this material limits the flow of charges therethrough from the inductor electrode and across the gap and such discharge thus may be caused to cease or be reduced. If the inductor electrode formed of a conductive material, such as a metal, is not provided with such a covering, the limiting action developed by the slightly conductive material is not secured and some variation of the output potential of the machine may occur. In electrostatic machines for certain purposes, for example for ignition purposes, however, such variation of potential is not detrimental and inductor electrodes without a covering of the slightly conductive material may be used. The limitation of discharge across the gap to the conveyor surface, also, may be secured all along the extent of the slightly conductive material between the two inductor electrodes.

The space between the face of the inductor electrode and the conveyor face, as well as between the high resistivity body and the conveyor, is made as small as possible and is made constant along the face of the conveyor in order to take advantage of the condition that the dielectric strength of the dielectric medium in the gap is increased as the space between the two parts at different potentials is decreased. A smaller gap makes possible a higher electric flux density which results in higher output current. The gap is maintained as constant as possible all along the conveyor face because it has been found that if the gap is of irregular width variation of the potential of the charges on the face of the conveyor will occur resulting in creeping discharges along the face of the conveyor.

The spacing of the ionizers from the face of the conveyor opposite to that adjacent which the inductor electrodes are disposed is made as small as possible without allowing these ionizers to touch the conveyor. The greater the gap through which the ions must pass in their movement from the input ionizer to the conveyor and from the conveyor to the output ionizer, the greater the loss of energy from the ions as they move through the fluid medium. Such loss of energy results in a drop of the potential of the charges and has a detrimental effect on the potential difference between the input and output terminals as well as on the overall efficiency of the machine.

If the insulating support of the ionizers is provided in the form of a continuous, even, regular surface adjacent the face of the conveyor that is opposite to that at which the inductor electrodes are disposed, it has been found that when the gap or space between this surface of the insulating support and the conveyor face is made as small and as constant as possible a further and substantial increase in the power output of the machine can be secured. The insulating support for the ionizers may, moreover, provide in its surface a recess in which the ionizer is disposed in order to secure effective ionization of the gaseous dielectric medium in contact with the ionizer and the adjacent face of the conveyor.

The input and output ionizers may be provided by wires or by thin blades disposed edgewise to the face of the conveyor. These wires or blades have their length extending transversely of the direction of relative movement of the conveyor with respect to the electrodes. The input and output ionizers both are disposed as close as possible to the adjacent face of the conveyor while avoiding contact therewith. The gaseous dielectric material is effective to prevent passage therethrough of current directly from one ionizer to the other, so that as the relative movement of the conveyor and electrodes is produced, the potential of the charges carried by the ions which are transported by the conveyor at its surface is increased from the potential at the input ionizer to the potential at the output terminal.

As indicated above, in order to secure effective operation of a machine utilizing the structures above described, a dielectric gaseous medium is disposed in the narrow spaces that are provided at either side of the conveyor. This gaseous medium at one side of the conveyor is in contact with the inductor electrodes and with the insulating body, or with a body of slightly conductive material when such body is used. The gaseous dielectric medium is in contact with the ionizers and the insulating support at the other side of the conveyor. This gaseous medium should have as high a dielectric strength as possible consistent with other qualities which are found to be requisite. It should have a high dielectric dependability which is the characteristic that the gaseous medium acts to trap the electrons so as to prevent an avalanche of electrons from developing into a long spark through this dielectric medium. The gaseous dielectric medium which is in contact with the ionizers also should have as high ionic mobility as possible in order to facilitate the transfer of the ions from the input ionizer to the conveyor and from the conveyor to the output ionizer. These qualities are secured by utilizing certain gases under high pressure of the order, for example, of 10 to 30 kg. per cm.^{2}. The gaseous medium further should be chemically inert under the conditions of ionization which prevail in the electrostatic machine in order to avoid corrosive action on the metallic and insulating parts of the machine.

For the purpose of securing high dielectric strength compressed oxygen, nitrogen, chlorine or oxygenated or halogenated compounds or mixtures of these gases may be used as heretofore proposed. Such gases would also have a good dielectric dependability. Dielectric dependability, however, is normally linked with electronic affinity, i. e., oxidizing properties which are characteristic of electronegative gases. Such oxidizing properties in the dielectric medium, especially where ionization takes place, are unsuitable because of their corrosive effect on the metal and insulating parts which would prevent continuous operation. Either pure hydrogen or pure nitrogen may be used for the gas at the ionizer side of the conveyor in order to prevent corrosion. Hydrogen is preferable since it meets to the requisite extent the requirements of chemical inertness and dielectric dependability.

In order to provide the desirable ionic mobility nitrogen or hydrogen, preferably hydrogen, free of electronegative impurities may be used at the side of the conveyor at which the ionizers are disposed. Pure hydrogen is particularly advantageous because it provides a very high ionic mobility and at the same time affords adequate dielectric strength and also adequate dielectric dependability.

In addition to the above described electrical and chemical advantages secured by the use of hydrogen as a dielectric gaseous medium, hydrogen because of its low density has the advantage that it makes possible the operation of the machine with small loss due to the frictional effect of windage, especially in the small spaces that are provided between the conveyor faces and the adjacent parts, namely, the bodies or supports of insulating or slightly conductive material, or the electrodes.

When the electrostatic machine is required to supply large currents the insulating material of which the conveyor is made should be capable of withstanding without danger of breakdown an electric flux density (product of the dielectric constant of the material and the electric field intensity) as high as possible. This material also should be capable of withstanding the intensive corona discharges prevailing around the ionizers. It has been found that in pure hydrogen or nitrogen the ability of the insulating material of the conveyor to withstand corona discharges for long intervals of time is primarily determined by the ability of this material to withstand spot carbonization. Such a material is one which will withstand "tracking," the phenomenon of the formation of conductive paths or tracks under the action of electric discharge between two spaced electrodes disposed in contact with the surface of the insulating material. (1952 Book of Standards, American Society for Testing Materials, designation D 495–48T). The dielectric constant of the insulating material which, for example, may be a suitable ceramic, glass or synthetic resin, advantageously is between four and ten times that of the gaseous dielectric medium in the space between the conveyor and the conductive electrodes.

Having regard to the explanation above given, preferably a gaseous medium such as hydrogen may be disposed at the side of the conveyor at which the ionizers are disposed in order to secure the advantage of ionic mobility and the other advantages referred to, while at the opposite side of the conveyor a gaseous medium providing primarily a high dielectric strength may be used. If two different gaseous mediums thus are to be used at the opposite sides of the conveyor it is necessary to provide means to insure their separation and the construction would require stuffing boxes and separating walls for confining these separate gases under pressure, and other complications. In a practical machine, therefore, it is found that hydrogen under a pressure of not substantially less than 8 kg. per cm.^{2} and preferably between 10 and 20 kg. per cm.^{2} may be used as a dielectric gaseous medium for securing in the requisite degree all of the qualities which have been described above. Within the scope of the invention a liquid dielectric medium having sufficient dielectric strength and dielectric dependability may be used at the side of the conveyor opposite to that at which the ionizers are disposed.

It is a further feature of the invention that the bodies of slightly conductive material and of insulating material that are disposed in close relation to the surface of the conveyor, especially in a machine in which the conveyor provides a surface of revolution about an axis of rotation, are supported by a stator which is of such form as to insure that the narrow space of constant width between the inductor members and the body of slightly conductive material or of insulating material is maintained. A stator of insulating material also is provided for supporting the ionizers at the opposite surface of the conveyor, which in a rotary machine may be a surface of revolution about the axis of rotation, in closely spaced relation to the conveyor surface while at the same time providing for the close spacing of this stator of insulating material with respect to the conveyor face. In such a rotary machine the conveyor and these stators preferably are of cylindrical form and preferably are hollow. The conveyor may be in the form of a hollow bell supported by a web at one end thereof on a rotatable shaft in cantilever relation to this shaft. One of the stators may be supported adjacent the outer surface of the cylindrical conveyor and the other stator may be supported so as to extend within the hollow space of the bell shaped conveyor in adjacent relation to the inner surface of the conveyor. These stators may be of cantilever form supported at one end thereof. The inner stator may be supported on the outer stator at an end thereof.

The mechanical form and disposition of the parts of the machine as well as the electrical features thereof will be understood more clearly from the description to follow taken in connection with the drawings in which:

Fig. 1 is a longitudinal, sectional view of such a machine on line I—I of Fig. 2.

Fig. 2 is a cross sectional view of said machine on line II—II of Fig. 1.

Fig. 3 is a diagram showing the principle of operation of the machine.

Fig. 4 is a diagram of electrical connections for the machine of Figs. 1 and 2.

Fig. 5 is a longitudinal, sectional view of a second embodiment on line V—V of Fig. 6.

Fig. 6 is a cross sectional view of this machine on line VI—VI of Fig. 5.

Fig. 7 shows in partial section the construction which utilizes the body of insulating material between the electrodes and the insulating support for the ionizers.

Figs. 8, 9, 10 and 11 show four forms of construction representing the improvement secured by the construction of Fig. 7, as compared with the prior art construction.

Referring now to Figs. 1 and 2, the machine according to the invention comprises a sealed cylindrical envelope **1** capable of withstanding an internal pressure of several tens of atmospheres, and which may be filled, for example, with pure hydrogen under a pressure of, say, 10 to 20 kg. per sq. cm. For the sake of simplicity, only the portion of this envelope which surrounds the essential parts of the machine has been shown.

At one end of the envelope **1** a shell shaped metal support **3** is secured by means of insulators **2**, this support comprising a protruding part **4** on which is attached an insulating flange **5**. On a circumferentially machined portion **6** of said flange is fitted a tubular, cylindrical part **7** made of insulating material in the inner cylindrical face of which are provided four longitudinal grooves **8** located in pairs on two perpendicular diameters. In two of these grooves that are diametrally opposite to each other are disposed two longitudinal metal members **9** which constitute the input inductor electrodes while electrode members **10** similar to members **9** are secured in two other grooves **8** located on the diameter that is perpendicular to the diameter on which metal members **9** are disposed. The members **10** are the screens or output inductor electrodes.

A cylindrical sleeve **11** made of a slightly conductive material, of the order of 10^{10} to 10^{13} ohms per centimeter per square centimeter, provided for instance, by a suitable resin, ceramic, or glass, is fitted inside the tubular part **7** and in contact with input inductor electrodes **9** and output inductor electrodes **10**.

A second hollow member **12** of insulating material and a generally cylindrical shape is attached to the tubular part **7** coaxially therewith by means of cooperating circumferentially machined bearing surfaces **13**. The member **12** also comprises, on its outer face, longitudinal grooves **14** which respectively face the grooves **8** in member **7**. Metal plates **15** facing the electrode **9** and metal plates **16** facing the output inductor electrode **10**, respectively, are secured at the bottom of these grooves **14** in the member **12**. Resilient tensioning members **17** are arranged at each end of the plates **15** and **16** for supporting, in each corresponding groove and substantially at the level of the periphery of member **12**, two metal wires **18, 19** which extend parallel with the axis of the machine. These pairs of metal wires are stretched by the tensioning members in the grooves **14** facing the electrodes **9** and **10** and serve respectively as the input and output ionizers.

Within the space between sleeve **11** and member **12** is disposed the skirt of a hollow, cylindrical, bell shaped insulating member **20** open at one end of the cylinder. This member **20** constitutes the conveyor. The conveyor **20** is keyed on a rotary shaft **21** extending along the axis of the machine and supported, on the one hand, by a ball bearing **22** housed in part **4** of support **3** and, on the other hand, by similar bearings **23** housed in a sheath **24** held in a support **25** connected with member **12** through webs **25a**. Shaft **21** is connected through an insulating coupling **21a** with a second shaft, not shown, which passes through the sealed envelope by means of a stuffing box and which may be driven in rotation by any suitable means such as an electric motor.

Input inductor electrodes **9** are electrically connected by conductors **26** to one of the terminals of a source of direct current potential, such as an auxiliary electrostatic generator **27** (Figs. 3 and 4), which charges these electrodes at a predetermined potential, the other terminal of this source being grounded in the particular embodiment shown. Input ionizers **18** are grounded through conductors **28**, thus establishing connection of the input ionizers to the "other" terminals of the machine. On the other hand, the output inductor electrodes **10** and output ionizers **19** are electrically connected through conductors **29** to the output terminal **30** of the machine (Figs. 3 and 4). Conductors **26**, **28** and **29** may be arranged to pass through suitable insulating bushings in envelope **1**. When the envelope **1** is made of metal it is advantageously grounded, in which case conductors **28** may be directly connected therewith.

The operation of the above described machine is explained hereinafter, reference being had to the diagram of Fig. 3 which represents, in developed form, an input inductor or exciter electrode **9** and an output inductor electrode or screen **10** spaced therefrom in the direction of movement of conveyor **20**, as shown by the arrow. Fragmentary portions of the conveyor **20** and of the slightly conductive sleeve **11** are shown, as well as the input ionizer **18** and the output ionizer **19** which are spaced in the direction of movement of the conveyor, together with the corresponding electrical connections.

Input inductor electrode **9** being brought by the auxiliary generator **27** to a potential $-V$ with respect to ground, an intense electric field is established adjacent ionizer **18** which is grounded and which faces inductor electrode **9**. As a result, positive charges are deposited on the face **20′** of insulating conveyor **20** which is disposed toward ionizer **18**. In the space between input inductor electrode **9** and the section of the other face **20″** of the conveyor **20** which is facing electrode **9**, free negative ions which exist in the dielectric medium are attracted by the above mentioned positive charges and as a result a layer of negative charges builds up on the face **20″** of the conveyor **20**.

During the movement of a section of the insulating conveyor **20** from the position facing the electrode **9** towards electrode **10** in the direction of the arrow, Fig. 3, the potential of the charges carried by this section increases. When this section comes to the position facing output ionizer **19** these charges flow through ionizer **19** and charge the output terminal **30** of the machine and the electrode **10** connected thereto which are thus brought to a potential +U. It may be shown that the amount of positive charges on the face **20'** of the insulating conveyor **20** due to the presence of negative charges on the face **20''** of the conveyor, is about twice that which would be developed if these negative charges did not exist. Such action is termed "double transport." A condition to be obtained for such operation is that the insulating material forming the conveyor **20** shall be able to withstand a dielectric stress double that to which it would be subjected if only one face of the conveyor were charged.

A purpose of the slightly conductive sleeve **11** is to avoid field concentrations on the lateral edges **9***a*, **10***a* of the inductor electrodes to distribute smoothly the gradient of the potential difference existing between an inductor **9** and the next inductor **10** in such a manner that the charges deposited on the conveyor move in a well distributed longitudinal field varying gradually without abrupt change in the vicinity of the electrodes. The sleeve **11**, on the other hand, may be omitted and the inner face of the insulating part **7** may be covered with a layer or coating of slightly conductive material to provide the electrical connection between electrodes **9** and **10** which establishes and maintains the desired longitudinal field.

The interval between sleeve **11** and the outer face **20''** of conveyor **20** should be as small as possible as above mentioned, namely, generally in the range between .1 mm. and 1.5 mm. This space preferably, however, has a width of the order of .1 to .5 mm. to secure the advantage above described of the narrow space.

The cylindrical shape adopted in the above described embodiment makes it possible to obtain a compact, simple and economical construction. Due to the fact that cylindrical surfaces are relatively easy to fabricate with precision, fluctuations or breakdown due to variations in the distance between the conveyor and the slightly conductive sleeve are avoided which fluctuations would affect the operation of the machine unfavorably if the machine were constructed with a flexible conveyor.

In the machine shown in Figs. 1 and 2 the inductor electrodes are disposed exteriorly of the conveyor while the ionizers are located within the hollow space of the conveyor. The converse arrangement also is possible, as shown in Figs. 5 and 6.

In Figs. 5 and 6 identical or similar parts to those of the machine in Figs. 1 and 2 are designated by the same reference numerals increased by 100. Thus, the machine again comprises a sealed envelope **101**, insulators **102** securing a support **103** on part **104** to which is fitted flange **105** which, by means of the cylindrical bearing surface **106**, supports the cylindrical member **107**. The insulating conveyor **120** is keyed on the shaft **121** rotatably mounted in the bearings **122** and **123**, the bearings **123** being housed in the ring **124** carried in the support **125** connected with the inner cylindrical part **112** through webs **125***a*.

In contrast to the machine of Figs. 1 and 2 it is the outer cylindrical member **107** which carries the ionizers. These ionizers in this embodiment are formed of thin metal blades **118** and **119**, respectively disposed on edge in two perpendicular diametral planes of the machine. These blades are supported by insulating rods **131** held at their ends in member **107**, being disposed in recesses formed in the wall of the cylindrical member **107**, these recesses opening through windows adjacent the outer surface of the conveyor wall. The metal blades **118**, **119** project through these windows into close relation to the outer surface of the conveyor.

On the other hand, it is the inside cylindrical part **112** which carries the electrodes **109** and **110** and on which is fitted the high resistivity sleeve **111**. The assembling of member **112** and of the other parts supported by this member is made easier and the whole is made lighter by forming depressions in the outer circumference of the part **112** in order to provide machined bosses, such as **112'** and **112''**, arranged in rows lengthwise and circumferentially of the part **112**, on which bear respectively the input inductor electrodes **109** and the output inductor electrodes **110** and the slightly conductive sleeve **111**, the free interstices between the bosses being filled with a cast compound which may consist of coal tar pitch, insulating synthetic resin or an insulating liquid.

The centering of member **112** and of the parts carried by this member is accomplished in relation to shaft **121** the end of which is supported by a bearing **132** housed in a flanged head **133** fitted into member **107**, one or more longitudinal ribs **134** being provided on this head engaging corresponding grooves in member **112** for preventing rotation of the member **112** relative to the head **133** and bearing **132**.

The construction of this machine, the operation of which is the same as that of the machine of Figs. 1 and 2, makes the necessary insulation easier. In addition, the adjustment of the positions of the ionizers **118** and **119** is made easier due to the fact that they are located on the outside and are, therefore, more easily accessible.

The two above described embodiments relate to cylindrical machines, but it will be appreciated that a machine according to the invention might also comprise one or more disc-shaped conveyors of insulating material, the inductors, on the one hand, and the ionizers, on the other hand, being arranged radially at the respective sides of each disc, the construction being such that the narrow spaces of constant width at the two sides of the conveyor disc are provided.

Although the machines of the invention have been described as operating as generators it will be understood that they can also operate as motors, a potential U being applied to the output inductor electrode **10** or **110** and to the output ionizer **19** or **119** and an excitation potential V being applied to the input inductor electrode **9** or **109**.

In Fig. 7 is shown diagrammatically a modification of the construction of the electrostatic machine of the invention in which an input inductor electrode **141** and an output inductor electrode **143** are disposed in spaced relation along and with their faces parallel to the adjacent face of a conveyor **145** of insulating material supported for movement in the direction of the arrow. The inductor electrodes **141** and **143** are supported by a stator **147** providing a body of insulating material disposed between the two inductor electrodes **141** and **143** and providing face **149** extending generally in the same plane as the face of the inductor electrodes **141**, **143** parallel to and in closely spaced relation to the adjacent face of the conveyor **145**. It will be understood in a machine having a rotatable conveyor which may be of cylindrical form that the stator **147** may have the form of the member **7** in Figs. 1 and 2 described above providing a cylindrical surface about the cylindrical conveyor. In the face **149** of the stator **147** recesses **151**, **153** are formed in a manner similar to Fig. 2, in which recesses the inductor electrodes **141**, **143** respectively are disposed. In the embodiment of Fig. 7, however, the slightly conductive body provided by the sleeve **11**, Figs. 1 and 2, is omitted and the conveyor **145** is disposed in closely spaced relation to the surface **149** of the stator and also in closely spaced relation to the adjacent faces of the inductor electrodes **141**, **143** as is the outer surface of the conveyor **20** in Figs. 1 and 2 with respect to the inner surface of the slightly conductive sleeve **11**. The width of this spacing in the construction of Fig. 7 may be of the same degree, namely .1 to 1.5 mm. In the embodiment of Fig. 7, as in the embodiments previously described, the narrow space is continuous and of substantially constant width along the length of the conveyor in the direction parallel to its movement relative to the stator **147**. The advantages above generally described with respect to control of the gradient of potential or the tangential field along the conveyor by virtue of this narrow space may be secured in the construction of Fig. 7.

At the opposite face of the conveyor **145** the input ionizer **155** and the output ionizer **157** are disposed respectively in opposed relation to the input inductor **141** and the output inductor **143**, the edges of these ionizers in the form of blades disposed perpendicular to the conveyor surface being in closely spaced relation thereto for the purpose of securing the requisite ionization of the gaseous medium. As shown in Fig. 7 ionizers **155** and **157** are supported by a stator **159** of insulating material providing a surface **161** extending parallel to and in closely spaced relation to the adjacent surface of the conveyor **145**. In the region adjacent the ionizers **155**, **157** recesses **163**, **165** are formed in the surface **161** of the stator **159** so as to provide spaces at either side of the respective ionizers **155**, **157** properly to provide for the ionization. Except for the recesses **163**, **165**, the space between the surface **161** and the conveyor face is maintained continuous and of constant width transversely of the conveyor face along the conveyor in the direction parallel to its movement. The width of this space may be substantially in the range between .1 mm. and 1.5 mm.

It will be understood that the stator **159** also may be provided in a rotary machine in a form similar to the stator **12** of Figs. 1 and 2 in which the outer circumferential surface recesses **14** extending parallel to the axis are formed in which the ionizers are disposed. The edges of the ionizers **155**, **157** are disposed approximately at the plane of the surface **161** of the stator **159**, Fig. 7, as are the ionizers **18**, **19**, Fig. 2, with respect to the outer circumference of the stator **12**. The mechanical forms of the stators **147**, **159** and of the conveyor **145** may be similar to the construction shown in Figs. 1 and 2, or, if desired, this construction may be similar to that of Figs. 5 and 6 in which the outer stator supports the ionizers and the inner stator supports the inductor electrodes.

It has been found by tests that the construction embodying the features which have been described in connection with Fig. 7 makes possible a substantial increase in power as compared with a machine of the same general dimensions excited by a potential of the same general degree across the input inductor electrode and the input ionizer when such input inductor electrode and ionizer merely are supported in opposed relation at opposite sides of the conveyor, as in Fig. 11, without utilizing the stators of insulating material in the form shown in Fig. 7. A comparison between three different constructions is given in Table I which has reference to Figs. 8, 9 and 10 of the drawings which are fragmentary sections showing merely schematically one of the inductor electrodes and the ionizer in opposed relation thereto of constructions utilizing statcrs one or the other or both of which are in the closely spaced relation to the conveyor described in connection with Fig. 7.

TABLE I

Fig. No.	Excitation Threshold	Optimum Excitation Potential	Output Current μA at Output Potentials—			
			0	50	60	80
8	14	18	140	90	80	70
9	19	27	130	------	100	90
10	14	19 to 20	187	155	------	140
11	18	22	90	50	46	------

The generator which was used for the tests of Table I was constructed with one input inductor electrode and one output inductor electrode with their respective ionizers. The outer diameter of the rotor was 88 mm.; the thickness of the rotor 2 mm., the length of the ionizers 60 mm. The rotor was rotated at 3,000 R. P. M. The casing was pressurized with hydrogen at 15 kg. per cm.^{2}. The thickness of the ionizer blades was .03 mm.

When the excitation voltage or the potential difference to be produced between the input inductor electrode and the input ionizer is below a certain threshold, no ionization takes place at the input ionizer and, therefore, no output current is produced by the machine. As the excitation voltage is increased above the threshold the output current increases as a function of the excitation voltage but a point is reached at which the current output is at a maximum and no further increase in current output is secured upon further increase of the excitation voltage. This point is identified in the table as the optimum excitation potential.

In Fig. 8 the inductor member **171** is supported on an insulating support **173** which, however, does not provide a body of insulating material or of the slightly conductive material extending along the conveyor face in closely spaced relation thereto. This construction, however, provides the insulating support **175** for the ionizer disposed in a recess **177** corresponding to the construction of Fig. 7 at the ionizer side of the conveyor, this insulating support or stator being in closely spaced relation to and continuous along the conveyor as is the stator **159** in Fig. 7. The improvement obtained in power output of the machine by the construction of Fig. 7 by virtue of the close spacing with respect to the conveyor surface of the body disposed between the two inductor members is shown by comparison with the results given in the table for the construction of Fig. 10 in which the inductor **141** is disposed in a recess **151** formed in an insulating body **147** having a surface **149** in continuous closely spaced relation to the conveyor **145** as in Fig. 7, the ionizer **155** being supported in Fig. 10 by the stator **159** in recess **163** the same as shown in Fig. 7. It will be understood by comparison of the data given with respect to Figs. 8 and 10 that the current in micro-amps is greatly increased both on a short circuit and at the high potential of 80 v. In the latter case the current is doubled.

The construction of Fig. 9 is the same as that of Fig. 7 with respect to the disposition of the inductor member **141** supported by stator **147** having its surface **149** in closely spaced relation to the conveyor **145**. In this construction, however, the ionizer **181** is supported by a bar **183** of insulating material without the body of the insulating supporting material closely adjacent to and continuous along the surface of the conveyor **145** at which the ionizer **181** is disposed as in the embodiment of Fig. 7. As shown in Table I it will be understood that the construction of Fig. 9, while providing an increase of current from 70 micro-amps to 90 micro-amps at 80 kv., does not provide the substantial increase to 140 micro-amps which is secured by the construction of Fig. 10. It will be clear, therefore, when the bodies which are disposed between the inductor members and between the ionizers at the respective sides of the conveyor are brought into closely spaced relation to and are continuous along the respective faces of the conveyor, that a significant improvement in the power which may be developed by the electrostatic machine is accomplished.

Fig. 11 shows a stator **173** supporting the inductor electrode **171** as shown in Fig. 8 and a stator **183** supporting the ionizer **181** as shown in Fig. 9, these stators at both sides of the conveyor being disposed adjacent but not in the continuous close spacing with respect to the conveyor as in Figs. 7 and 10. Fig. 11 corresponds in a general way to constructions of the prior art, the output current by comparison with the output current obtained with the constructions of Figs. 8 and 9, and particularly with respect to Fig. 10, being very much reduced, as shown in Table I. Moreover, in the test of the construction of Fig. 11 it was found that it was impossible to increase the output potential above 60 kv. because internal breakdown prevented reaching a higher output potential than 60 kv. Thus, it will be clear that the continuous close spacing of the stators to the respective adjacent surfaces of the conveyor constitutes an important improvement.

A similar significant improvement in power output is secured by virtue of the closely spaced relation which has been described in the construction which utilizes the slightly conductive material.

In any of the embodiments which have been described above thin blades set edgewise to the adjacent surface of the conveyor are preferable for the ionizers. These blades should be as thin as possible to insure proper ionization. Having regard to the necessity for mechanical strength and rigidity it is found that a metal blade, for example, of steel, having a thickness substantially in the range of .01 mm. and .05 mm. may be used.

The embodiments of Figs. 1 and 2 and of Figs. 5 and 6 provide a conveyor of bell shape, that is, the hollow cylinder **20**, **120** supported at one end thereof by a web or flange **191** connecting the cylindrical wall of the conveyor to a hub **193** carried on the shaft **21**, **121**. The web **191** and the hub **193** are disposed at the end of the conveyor toward the insulating flange support **5**, **105**. The opposite end of the hollow conveyor is open so as to leave unobstructed the space within the cylindrical wall for insertion of the stator **12**, **112** which in Figs. 1 and 2 support the ionizers and in Figs. 5 and 6 support the inductor electrodes as above described. In the embodiments of Figs. 1 and 2 and Figs. 5 and 6, this inner stator also supports bearings **23**, **123** which are outboard with respect to the supporting flange **5**, **105**. The outer stator **7**, **107** is supported in cantilever relation to the supporting flange **5**, **105** and, at its end opposite to the supporting flange **5**, **105**, supports the inner stator **12**, **112** in cantilever relation to this opposite end of the outer stator.

The bell shape cylindrical conveyor provides a form which may be fabricated to precise dimensions and provides a hollow space of substantial diameter within which an inner stator of correspondingly substantial diameter may be disposed to support either the ionizers or the inductor electrodes in the closely spaced relation to the conveyor face in the manner which has been described above. This inner stator, also being of cylindrical form, may be fabricated easily to precise dimensions and may be fitted closely to the outer stator in the cantilever relation thereto which has been referred to. Moreover, since the outer stator also is of general cylindrical form it may be made to precise dimensions both with respect to the inner stator and with respect to the supporting flange **5**, **105** which, in the embodiments disclosed, is carried upon the protruding part **4**, **104** which supports the bearing **22**, **122** for the shaft **21**, **121**. Thus, the two stators and the conveyor disposed therebetween may be maintained in the closely spaced relation and concentric with the axis of the shaft so that the conveyor will run true in relation to the adjacent stator surfaces.

Without departing from the invention variations may be made in the dimensions of the conveyor and of the stators and in the thickness and disposition of the slightly conductive body, while retaining the features and securing the advantages of the invention which have been described above. The stators and the conveyor may be made of different materials, including different plastics, to secure the requisite properties which have been referred to in connection with these members of the machine. Different materials also may be used for the slightly conductive body disposed in contact and connecting the inductor electrodes. Different metals or other conductive materials may be used for the inductor electrodes and the ionizers. These and other variations which may be made by those skilled in the art are intended to come within the scope of the appended claims.

This application is a continuation-in-part of my copending application Serial No. 321,351, filed November 19, 1952.

I claim:

1. An electrostatic machine comprising an input inductor electrode, an input ionizer disposed in opposed spaced relation to said input inductor electrode and maintained at a potential with respect to the potential of said electrode to provide therebetween an electric field, a conveyor of insulating material providing at opposite faces thereof generally parallel surfaces, means for supporting said conveyor and said electrode for movement of one with respect to the other in the direction transverse to said electric field and parallel to said faces of said conveyor with said conveyor disposed between said inductor electrode and said ionizer, an output inductor electrode disposed at the same side of said conveyor as said input inductor electrode and spaced from said input inductor electrode in the direction of movement of said conveyor relative to said input inductor electrode, an output ionizer disposed at the same side of said conveyor as said input ionizer and in opposed relation to said output inductor electrode, said conveyor being supported also for movement of said conveyor and said output inductor electrode one with respect to the other in said direction of relative movement of said input inductor electrode and said conveyor with said conveyor disposed between said output inductor electrode and said output ionizer, a body having a resistivity not substantially less than 10^{10} ohms per cm. per cm.^{2} extending between said two inductor electrodes in contact therewith and providing a surface extending parallel to the adjacent surface of said conveyor and spaced from said conveyor surface by a narrow continuous space of substantially constant width transversely of said surfaces and extending along said conveyor surface parallel to the direction of movement thereof, and means for confining a dielectric fluid medium in contact with said inductor electrodes, said ionizers and the faces of said conveyor adjacent thereto.

2. An electrostatic machine as defined in claim 1 in which the resistivity of said body is substantially in the range between 10^{10} and 10^{13} ohms per cm. per cm.^{2}.

3. An electrostatic machine as defined in claim 1 in which the resistivity of said body is not substantially less than 10^{14} ohms per cm. per cm.^{2}.

4. An electrostatic machine as defined in claim 1 in which the width of said space between said body and the adjacent face of said conveyor is substantially in the range between .10 mm. and 1.5 mm.

5. An electrostatic machine as defined in claim 1 in which said dielectric fluid medium in said space is a gas at a pressure not substantially less than 10 kg. per cm.^{2}.

6. An electrostatic machine as defined in claim 1 which comprises a body having a resistivity not substantially less than 10^{14} ohms per cm. per cm.^{2} extending between said two ionizers and providing a surface extending parallel to the surface of said conveyor that is adjacent said ionizers and spaced from said adjacent conveyor surface by a narrow continuous space of substantially constant width transversely of said surfaces and extending along said conveyor surface parallel to the direction of movement thereof.

7. An electrostatic machine as defined in claim 6 in which said body disposed between said ionizers is continuous along said conveyor surface at either side of said ionizers in the direction parallel to said movement of said conveyor and provides an insulating support for said ionizers, said ionizer supporting body providing respectively at the positions of said ionizers recesses in said surface of said body open toward said conveyor to provide space at the sides of said ionizers for insuring effective ionization by said ionizers of said fluid dielectric medium in contact with said ionizers.

8. An electrostatic machine as defined in claim 1 in which said dielectric fluid medium in contact with said ionizers and the adjacent face of said conveyor is a gas having a high ionic mobility at a pressure not substantially less than 8 kg. per cm.^{2}.

9. An electrostatic machine as defined in claim 1 in which said dielectric fluid medium in contact with said ionizers and the adjacent face of said conveyor is hydrogen.

10. An electrostatic machine as defined in claim 1 in which said dielectric fluid medium in contact with said ionizers and the adjacent face of said conveyor is nitrogen.

11. An electrostatic machine as defined in claim 1 in which said fluid medium in contact with said ionizers and the adjacent face of said conveyor is hydrogen at a pressure substantially in the range between 8 and 20 kg. per cm.^{2}.

12. An electrostatic machine as defined in claim 11 in which said fluid medium in said narrow space between said body and the conveyor surface adjacent thereto is hydrogen at a pressure substantially in the range between 8 and 20 kg. per cm.^{2}.

13. An electrostatic machine comprising a rigid conveyor of insulating material providing at opposite faces thereof generally parallel continuous even surfaces, a pair of inductor electrodes disposed in spaced relation to each other along and adjacent and in spaced relation to a given face of said conveyor, a pair of ionizers respectively disposed in opposed relation to said inductor electrodes at the opposite face of said conveyor from said inductor electrodes and adjacent and in spaced relation to said opposite face of said conveyor, means for confining in contact with said ionizers and said opposite face of said conveyor a gaseous dielectric medium, means connected to a given one of said inductor electrodes and the ionizer in opposed relation thereto for developing between said given electrode and the opposed ionizer a difference of potential capable of effecting ionization of said gaseous medium for depositing charges on said opposite face of said conveyor, means for supporting said conveyor for movement of said conveyor parallel to said faces thereof in the direction from said given inductor electrode and its opposed ionizer to said other inductor electrode and its opposed ionizer for conveying said charges on said opposite face of said conveyor adjacent which said ionizers are disposed, said other ionizer being disposed in relation to said opposite face of said conveyor for collecting said charges from said opposite face of said conveyor at a potential increased with respect to the potential of said given ionizer, a body having a resistivity not substantially less than 10^{10} ohms per cm. per cm.^{2} extending between said inductor electrodes and in contact therewith, said body and said inductor electrodes providing a substantially continuous even surface extending parallel to said given conveyor face and separated from said given conveyor face by a continuous narrow space of substantially constant width along said surface of said body and along the surface of said inductor electrodes disposed toward said conveyor, the width of said space perpendicular to said face of the conveyor and said surface of said body being substantially in the range between .10 mm. and 1.5 mm., and means for confining in contact with said inductor electrodes and in said narrow space a dielectric gaseous medium having high dielectric strength.

14. An electrostatic machine comprising a rigid conveyor of insulating material providing at opposite faces thereof generally parallel continuous even surfaces, a pair of inductor electrodes disposed in spaced relation to each other along and adjacent and in spaced relation to a given face of said conveyor, a pair of ionizers respectively disposed in opposed relation to said inductor electrodes at the opposite face of said conveyor from said inductor electrodes and adjacent and in spaced relation to said opposite face of said conveyor, means for confining in contact with said ionizers and said opposite face of said conveyor a gaseous dielectric medium, means for supporting said conveyor for movement of said conveyor parallel to said faces thereof in the direction from a given inductor electrode and its opposed ionizer to the other inductor electrode and its opposed ionizer for conveying charges on said opposite face of said conveyor adjacent which said ionizers are disposed, a body having a resistivity substantially in the range between 10^{10} and 10^{13} ohms per cm. per cm.^{2} extending between said inductor electrodes and connected thereto, said body and said inductor electrodes providing a continuous even surface extending parallel to said given face of said conveyor and separated from said given conveyor face by a continuous narrow space of uniform width along said surface of said body between said inductor electrodes and along said inductor electrodes, and means for confining in said space a gaseous dielectric medium at a pressure not substantially less than 10 kg. per cm.^{2}.

15. An electrostatic machine as defined in claim 14 in which said body has a thickness transverse to said surface thereof substantially uniform along the length thereof between said inductor electrodes and extends upon the faces of said inductor electrodes that respectively are disposed toward said conveyor and in contact with said faces to provide said continuous even surface and a smooth gradient of potential between said inductor electrodes.

16. An electrostatic machine comprising a conveyor of hollow cylindrical form supported for rotation on the axis of the cylinder, said conveyor being formed as a rigid body of insulating material, a conductive input electrode disposed adjacent a given face of and extending along the wall of said cylinder parallel to the axis thereof, an ionizer of elongated form disposed adjacent said cylinder wall adjacent the opposite face from and in opposed relation to said input inductor electrode with the length of said ionizer extending along said cylinder wall parallel to said axis of said cylinder, said ionizer throughout the length thereof having the dimension thereof which is transverse to said length thereof and which is generally parallel to the circumference of said cylinder restricted to provide a surface along said ionizer disposed toward said cylindrical wall capable of developing adjacent said ionizer a high flux density of an electric field produced between said input electrode and said ionizer upon establishing a potential difference between said input electrode and said input ionizer, an output inductor electrode circumferentially spaced about said axis of rotation from said input inductor electrode and adjacent said given face of said conveyor adjacent which said input inductor electrode is disposed, said output inductor electrode extending along the wall of said cylindrical conveyor parallel to said axis of rotation thereof, an output ionizer disposed adjacent said opposite face of said conveyor wall in opposed relation to said output inductor electrode with its length extending along said cylinder wall parallel to said axis of said cylinder, said output ionizer throughout the length thereof having the dimension thereof which is transverse to said length and which is generally parallel to the circumference of said cylinder restricted to provide a surface along said ionizer disposed toward said cylindrical conveyor wall capable of developing adjacent said output ionizer a high flux density of an electric field between said output inductor electrode and said output ionizer, means for confining in contact with said opposite face of said conveyor adjacent said ionizers and in contact with said ionizers a gaseous dielectric medium at a pressure not substantially less than 10 kg. per cm.^{2}, a body having a resistivity not substantially less than 10^{10} ohms per cm. per cm.^{2} extending between said inductor electrodes and in contact therewith and providing a surface adjacent said given face of said cylindrical conveyor wall spaced from said given face of said cylindrical conveyor wall, the space between said surface of said body and said given face of said conveyor wall being continuous and of uniform width circumferentially along said

conveyor wall, the width of said space being between .10 mm. and 1.5 mm., and means for confining in said space and in contact with said inductor electrodes and with said surface of said body and in contact with the given face of said cylindrical conveyor wall a gaseous dielectric medium at a pressure not substantially less than 10 kg. per $cm.^2$.

17. An electrostatic machine as defined in claim 16 in which said gaseous dielectric medium in contact with said ionizers is hydrogen.

18. An electrostatic machine as defined in claim 16 in which both of said gaseous dielectric mediums are hydrogen.

19. An electrostatic machine comprising a conveyor having a wall of insulating material extending about an axis of rotation and about a hollow space within said wall, said conveyor wall providing an outer surface of revolution and an inner surface of revolution about said axis, an outer stator of said machine having a wall extending about said axis and providing an inner surface of revolution about said axis, an inner stator of said machine having a wall extending about said axis and providing an outer surface of revolution about said axis, said outer and inner stator walls being disposed respectively outwardly and inwardly with respect to and adjacent said outer and inner surfaces of revolution of said conveyor wall, a rotatable driving element, means supporting said driving element for rotation thereof on said axis of rotation, said conveyor wall adjacent an end thereof being supported on said driving element in cantilever relation to said driving element so as to be disposed between said stator walls and for rotation of said conveyor wall with said driving element on said axis of rotation, and means disposed adjacent said driving element supporting means and supporting said outer and inner stator walls with said inner and outer surfaces of revolution thereof respectively adjacent the inner and outer surfaces of revolution of said conveyor wall.

20. An electrostatic machine as defined in claim 19 which comprises means disposed adjacent said supported end of said conveyor wall for supporting said outer stator wall in cantilever relation to said stator wall supporting means and in said adjacent relation to said outer surface of said conveyor wall.

21. An electrostatic machine as defined in claim 20 which comprises means disposed adjacent the end of said outer stator wall spaced along said axis of rotation from said supported end of said conveyor wall for supporting said inner stator wall in cantilever relation to said outer stator wall in said adjacent relation to the inner surface of said conveyor wall.

22. An electrostatic machine as defined in claim 19 in which said means supporting said driving element for rotation thereof on said axis comprises bearing means supported by said inner stator.

23. An electrostatic machine as defined in claim 19 which comprises a bearing support supported by said outer stator wall adjacent the end of said outer stator wall spaced along said axis from said conveyor wall supporting means and disposed within said inner stator wall for supporting said driving element.

24. An electrostatic machine as defined in claim 19 in which said outer stator is formed with a recess in the wall thereof extending parallel to said axis of rotation and open through said wall at said inner surface thereof, and an ionizer supported by said outer stator and disposed within said recess in adjacent ionizing relation to the outer surface of revolution of said conveyor wall.

25. An electrostatic machine as defined in claim 19 in which said inner stator wall is provided with a recess extending parallel to said axis of rotation and formed in the outer surface of revolution of said stator, and an ionizing element disposed in said recess and extending along said axis.

26. An electrostatic machine comprising a conveyor having a wall of insulating material extending about an axis of rotation and about a hollow space within said wall, said wall providing an outer cylindrical surface and an inner cylindrical surface concentric with said axis, an outer stator of said machine having a wall extending about said axis providing an inner cylindrical surface concentric with said axis, an inner stator of said machine having a wall extending about said axis and providing an outer cylindrical surface concentric with said axis, said cylindrical surfaces of said outer and inner stator walls being disposed respectively outwardly and inwardly with respect to and adjacent said outer and inner cylindrical surfaces of said conveyor wall and separated respectively therefrom by a narrow annular space of constant width concentric with said axis of rotation, a rotatable driving element, means supporting said driving element for rotation thereof on said axis of rotation, said conveyor wall adjacent an end thereof being supported on said driving element in cantilever relation to said driving element so as to be disposed between said stator walls and for rotation of said conveyor wall with said driving element on said axis of rotation, and means disposed adjacent said supported end of said conveyor wall supporting means and supporting said outer and inner stator walls with said inner and outer cylindrical surfaces of revolution thereof concentric with said axis and respectively in said narrow spaced relation to said inner and outer cylindrical surfaces of said conveyor wall.

27. An electrostatic machine comprising a conveyor having a wall of insulating material extending about an axis of rotation and about a hollow space within said wall, said conveyor wall providing an outer surface of revolution and an inner surface of revolution about said axis, an outer stator of said machine having a wall extending about said axis and providing an inner surface of revolution about said axis, an inner stator of said machine having a wall extending about said axis and providing an outer surface of revolution about said axis, said outer and inner stator walls being disposed respectively outwardly and inwardly with respect to and adjacent said outer and inner surfaces of revolution of said conveyor wall, a rotatable driving element, means supporting said driving element for rotation thereof on said axis of rotation, said conveyor wall adjacent an end thereof being supported on said driving element in cantilever relation to said driving element so as to be disposed between said stator walls and for rotation of said conveyor wall with said driving element on said axis for rotation, and means disposed adjacent said supported end of said conveyor wall for supporting said outer and inner stator walls with said inner and outer surfaces of revolution thereof respectively adjacent the outer and inner surfaces of revolution of said conveyor wall.

28. An electrostatic machine comprising an input inductor electrode, an input ionizer disposed in opposed spaced relation to said input inductor electrode and maintained at a potential with respect to the potential of said electrode to provide therebetween an electric field, a conveyor of insulating material providing at opposite faces thereof generally parallel surfaces, means for supporting said conveyor and said electrode for movement of one with respect to the other in the direction transverse to said electric field and parallel to said faces of said conveyor with said conveyor disposed between said inductor electrode and said ionizer, an output inductor electrode disposed at the same side of said conveyor as said input inductor electrode and spaced from said input inductor electrode in the direction of movement of said conveyor relative to said input inductor electrode, an output ionizer disposed at the same side of said conveyor as said input ionizer and in opposed relation to said output inductor electrode, said conveyor being supported also for movement of said conveyor and said output inductor electrode one with respect to the other in said direction of relative movement of said input inductor

electrode and said conveyor with said conveyor disposed between said output inductor electrode and said output ionizer, a body having a resistivity not substantially less than 10^{10} ohms per cm. per $cm.^2$ extending between said two inductor electrodes and providing a surface extending parallel to the adjacent surface of said conveyor and spaced from said conveyor surface by a narrow continuous space of substantially constant width transversely of said surfaces and extending along said conveyor surface parallel to the direction of movement thereof, means for confining in said space a dielectric fluid medium, and means for confining a gaseous dielectric medium in contact with said ionizers and the face of said conveyor adjacent said ionizers.

29. An electrostatic machine comprising a conveyor having a wall of insulating material extending about an axis of rotation and about a hollow space within said wall, said conveyor wall providing an outer surface of revolution and an inner surface of revolution about said axis, an outer stator of said machine having a wall extending about said axis and providing an inner surface of revolution about said axis, an inner stator of said machine having a wall extending about said axis and providing an outer surface of revolution about said axis, means for supporting said outer and inner stator walls with said inner and outer surfaces of revolution thereof respectively outwardly and inwardly with respect to and adjacent said outer and inner surfaces of revolution of said conveyor wall, a rotatable driving element, and means supporting said driving element for rotation thereof on said axis of rotation, said conveyor wall adjacent an end thereof being supported on said driving element in

cantilever relation to said driving element so as to be disposed between said stator walls and for rotation of said conveyor wall with said driving element on said axis of rotation.

30. An electrostatic machine comprising a rotor having a wall of insulating material extending about an axis of rotation and about a hollow space within said wall, said rotor wall providing an outer surface of revolution and an inner surface of revolution about said axis, an outer stator of said machine having a wall extending about said axis and providing an inner surface of revolution about said axis, an inner stator of said machine having a wall extending about said axis and providing an outer surface of revolution about said axis, means for supporting said outer and inner stator walls with said inner and outer surfaces of revolution thereof respectively outwardly and inwardly with respect to and adjacent said outer and inner surfaces of revolution of said rotor wall, a rotatable driving element, and means supporting said driving element for rotation thereof on said axis of rotation, said rotor wall adjacent an end thereof being supported on said driving element in cantilever relation to said driving element so as to be disposed between said stator walls and for rotation of said rotor wall with said driving element on said axis of rotation.

References Cited in the file of this patent

UNITED STATES PATENTS

2,058,732	Simon	Oct. 27, 1936
2,697,793	Trump et al.	Dec. 21, 1954