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IONIC DIODE DEVICE

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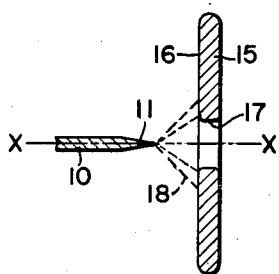


Fig. 1

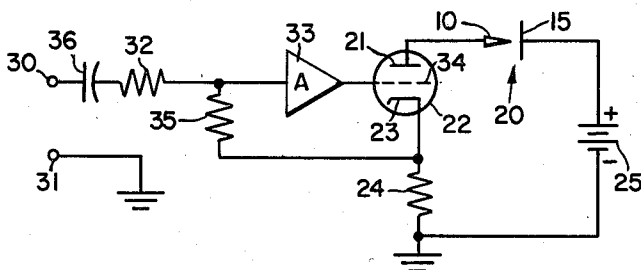


Fig. 2

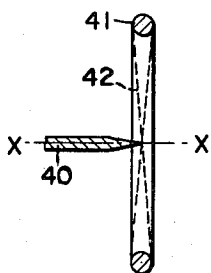


Fig. 3

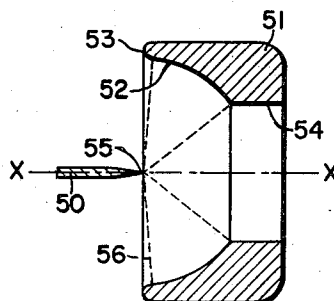


Fig. 4

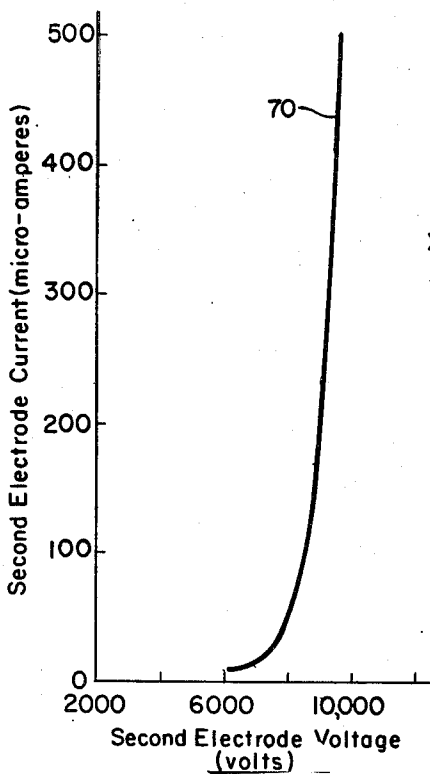


Fig. 6

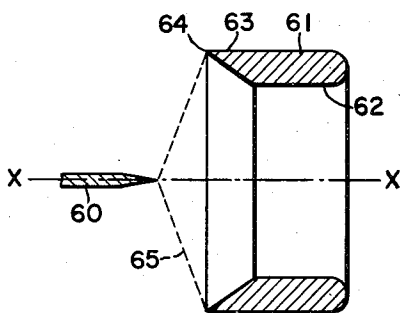


Fig. 5

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IONIC DIODE DEVICE

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18 Claims. (Cl. 315—163)

(Granted under Title 35, U. S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates to a new and novel ionic diode device and more particularly to an ionic diode device wherein an ion flow is established between two electrodes and a means is provided for controlling the ion flow to accomplish the purposes of the invention.

Although the present invention is adapted for use in various applications, it is especially adapted for use as a loud-speaker. In sound reproducing systems the loud-speaker presents the most serious problems in faithfully reproducing signals. Conventional loud-speakers employ electromagnetic arrangements wherein cones or diaphragms of various types are caused to vibrate by magnetic, electrostatic or piezo-electric means, and in response to vibrations of the cones or diaphragms the air is caused to vibrate correspondingly, thus producing sound. Such conventional loud-speakers have a number of inherent disadvantages which cannot be eliminated with conventional constructions. The disadvantages of such constructions may be generally termed their mechanical impedance which is due to the mass, compliance and resistance of these devices. The mass of such a system consists of the effective mass that the coil and cone assembly offer to the vibratory frequency involved plus the fluid mass of the air in contact with the vibratory element. The equivalent compliance is determined by the vibratory element suspension, the coil mounting and closed air spaces. The effective resistance to motion includes such factors as eddy current losses and sound energy radiated.

As a consequence of the previous factors affecting the operation of conventional loud-speakers, all of such speakers are characterized by the fact that they may have one or more resonant frequencies such that a flat response is not obtainable within the audio range involved in loud-speaker operation. The net result is that all conventional loud-speakers suffer certain limitations which prevent the desired degree of faithfulness in sound reproduction.

The present invention utilizes an arrangement wherein a first fixed elongated electrode is spaced from a second fixed electrode and a D. C. potential is impressed across these electrodes, the D. C. potential being of such a magnitude that an ion flow between the electrodes is produced resulting in corona. The ion flow between the electrodes may be controlled by varying the D. C. potential impressed upon the two electrodes, and in this manner the ion flow may be modulated. It is emphasized that the D. C. potential must be maintained below arcing potential for any given configuration of electrodes since if an arc is produced, the device will not operate in the proper manner because the ion flow in such a state is not sufficiently controllable to obtain linear results and further the arc itself will produce undesired noise.

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It is apparent that the present invention employs a construction which has no moving parts, and accordingly the disadvantages inherent in prior art systems due to mechanical impedance are entirely eliminated. In addition, the present invention operates in atmosphere whereby no particular enclosure is necessitated to ensure satisfactory operation. A loud-speaker constructed according to the present invention has a substantial linear region of operation such that a flat response is obtainable in the audio range frequencies and the device does not have any resonant frequencies, whereby peaks are substantially eliminated during operation.

The exact manner of operation is not well-known at this time, but the principle as presently understood is set forth hereinafter. When an electrical field is established in a gas and the magnitude of the field is increased, the gas breaks down in two major steps. The first step is a breakdown at either one or both of the electrodes, and the second step is a breakdown of the entire air gap between the electrodes. A manifestation of breakdown or discharge at the electrodes themselves is the emission of light, generally termed corona. As the potential is further increased, current flow increases until spark potential is reached at which time an instantaneous transition occurs and the entire air gap breaks down into an arc.

Breakdown in the corona region generates no appreciable amount of heat whereas breakdown in the arc region is accompanied by a large increase in heat and thermionic emission occurs. An undulating arc, as is well known, produces sound which may be termed noise of a high order. If such an arc is modulated by an audio signal, a degree intelligible sound is obtained but the output of such a device is a summation of the inherent noise generated by the arc and the intelligible sound. It is obvious that such a device is of no real value in faithfully reproducing sound such as is desired in conventional loud-speakers and devices of this type were demonstrated at the turn of the twentieth century as a novelty, but no further development or practical use has been made of such devices. In contrast to the high noise level of an arc, the present device employs a controlled corona which has a low inherent noise level making the device practical for sound reproduction purposes. It should be noted that the ionization produced in the present invention is largely due to ionization by collision and partly by photoelectric effect in contrast to the thermionic emission which is utilized in conventional vacuum tubes, for example. As a result, the present invention will operate in various gaseous substances at standard atmospheric pressures or above or below such pressures.

In the present invention, a D. C. potential of relatively high magnitude is impressed across the first and second electrodes thereof. The first electrode is provided with an elongated configuration having a relatively small emission area. A second electrode may be formed in various configurations and is provided with a collecting area which is substantially larger than the emission area of the first electrode. The potential gradient between the first and second electrodes is of sufficient magnitude to cause ions to flow between the two electrodes thereby establishing a static condition wherein an ion beam is produced between the two electrodes. In the static condition within the limits of range of the operating potentials employed when the device is operating as a loud-speaker, there is no propagation of sound within the audio spectrum. As the potential between the first and second electrodes is varied, the current flow between the electrodes varies directly with such potential variations; and accordingly, as a control voltage is impressed on the bias voltage between the two electrodes, an ionic flow proportional to the current flow between the electrodes is

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obtained therebetween which in turn causes a release of energies that result in audible sound. The sound produced is consequently a faithful reproduction of the currents caused to flow as a result of control voltages impressed upon the electrodes of the device. Apparently the dynamic ionic flow causes physical vibrations in the atmosphere adjacent to the device which set up sound waves in the air which in turn are propagated in a conventional manner.

An object of the present invention is to provide an ionic diode device which is operable in atmosphere and employs no moving parts.

Another object is to provide a new and novel loud-speaker which has no resonant frequencies and which provides a flat response in the audio range.

A further object of the invention is to provide an ionic diode device which is simple and inexpensive in construction yet sensitive and reliable in operation.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

Fig. 1 is a cross-sectional view of an electrode configuration according to the present invention;

Fig. 2 is a schematic diagram of an electrical circuit employing an ionic diode device according to the present invention;

Fig. 3 is a cross-sectional view of a modified electrode construction;

Fig. 4 is a cross-sectional view of a further modified electrode construction;

Fig. 5 is a cross-sectional view of another modified electrode construction;

Fig. 6 is a graph illustrating the characteristics of the device shown in Fig. 5.

Referring now to the drawings, there is shown in Fig. 1 a first electrode 10 formed of a suitable electrically conductive substance such as a metal rod, for example, the outer end 11 or emitting portion of the electrode being preferably tapered to a sharp point, although it is not necessary to taper the electrode at all if it is made of a sufficiently small diameter such that the electrical field emanating from electrode 10 is effectively concentrated near the tip of the electrode. It is essential that the field be concentrated at the emitting area of electrode 10 which is preferably the extreme outer end thereof whereby a corona is produced enabling an ion flow to be generated.

A second electrode 15 formed of a suitable electrically conductive substance such as steel or copper is spaced from electrode 10, the surface 16 of electrode 15 providing a collecting area for the ions flowing from electrode 10 to electrode 15. Electrode 10 has a longitudinal axis X—X extending therethrough as shown in Fig. 1 and electrodes 10 and 15 are formed symmetrically about this axis. Accordingly, electrode 10 has a generally cylindrical configuration, and electrode 15 is formed as a circular plate having a circular opening 17 extending therethrough. Electrodes 10 and 15 may be supported in position by any suitable means (not shown) preferably formed of insulating material, and electrical connections may be made with the electrodes in a well-known manner. When a suitable D. C. potential is impressed across electrodes 10 and 15, a corona is produced and a relatively well-defined area of intense ion flow is created between electrodes 10 and 15. This area of ion flow will assume a generally conical configuration and is indicated by dotted lines 18 in Fig. 1.

Opening 17 formed centrally in electrode 15 provides an area of dielectric material, in this case air, which is aligned with the longitudinal axis of electrode 10 and assists in producing the desired configuration of the corona or area of intense ion flow, and at the same time provides an opening whereby sound waves may be trans-

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mitted through electrode 15 such that the volume of the device is substantially increased over that obtainable when no opening is provided. It should be noted, however, that such an opening is not essential for operation of the device, and opening 17 may be filled with a suitable dielectric substance such as plastic or the like. In either case, it is apparent that the dielectric substance positioned within electrode 15 ensures the desired configuration of the corona area. In a typical construction of the device shown in Fig. 1, cathode 10 may have a diameter of 0.037 inch and may be spaced 0.375 inch from electrode 15. The thickness of electrode 15 may be 0.125 inch and the diameter of opening 17 may be 0.375 inch. These dimensions are merely provided for the purpose of illustration and should not be construed as critical or restrictive.

Fig. 2 illustrates an electrical circuit wherein the device as shown in Fig. 1 which is illustrated schematically at 20 is employed as a loud-speaker. The first electrode 10 of the diode device is connected to the plate 21 of a conventional triode 22, the cathode 23 of which is connected through a resistor 24 to ground. The negative terminal of a suitable source of D. C. bias potential such as a battery 25 is connected to ground, and the second electrode 15 of the diode device is connected to the positive terminal of source 25. Battery 25 provides a D. C. potential on the order of 10,000 volts which is sufficient to produce a corona and ion flow between the first and second electrodes 10 and 15. It is apparent that depending upon the dimensions and configuration of the first and second electrodes, the characteristics of the ionic diode device will vary and for any given configuration the D. C. bias potential is selected such that in a static condition the diode device will be biased to the midpoint of the most linear portion of its static curve wherein anode voltage is plotted versus anode current.

An input control voltage is impressed across terminals 30 and 31 of the circuit shown in Fig. 2, terminal 31 being connected to ground. Terminal 30 is connected through a capacitor 36 and resistor 32 to a high gain D. C. amplifier 33 which in turn is connected to the grid 34 of tube 22. A resistor 35 additionally connects the input of amplifier 33 to the cathode 23 of tube 22 whereby resistors 32 and 35 serve as a summing network for amplifier 33 and resistor 24 serves as a feedback resistor whereby an inverse current feedback to the amplifier produces linearity in the amplitude of the output of the loud-speaker.

In operation of the circuit shown in Fig. 2, the circuit is normally biased in its static condition by battery 25 whereupon an A. C. control signal is impressed across input terminals 30 and 31. Amplifier 33 produces a signal on the grid 34 of tube 22 whereby the potential drop across tube 22 is varied such that the current flow between electrodes 10 and 15 is varied. Upon a change in the current flow between electrodes 10 and 15, the ionic flow between the electrodes is correspondingly altered thereby producing sound such that diode device 20 serves as a loud-speaker which faithfully reproduces the signal impressed upon input terminals 30 and 31.

In each of the modifications disclosed hereinafter the first electrode corresponds to electrode 10 of device shown in Fig. 1 and the second electrode corresponds to electrode 15 of the device shown in Fig. 1. It is evident that the first and second electrodes of each modification may be connected in a suitable electrical circuit such as shown in Fig. 2 in the same manner that electrodes 10 and 15 are connected, with corresponding results.

Fig. 3 illustrates a modification wherein a first electrode 40 thereof is identical with the electrode 10 of Fig. 1, and the second electrode 41 has a substantially annular configuration. The cross sectional diameter of the body of the annular shaped electrode 41 may be 0.187 inch and the diameter of the inner hollow portion of electrode 41 may be 0.782 inch. It is apparent that

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in this type of an arrangement, the ionic beam travels radially outward from electrode 40 to electrode 41 and the corona area is circular with a configuration as illustrated in dotted lines 42. It is evident that the annular configuration of the second electrode provides a large central opening through which sound may be emitted when the device is operated as a loud-speaker.

Fig. 4 illustrates a modification wherein a first electrode 50 is identical with electrode 10 of the device shown in Fig. 1 and a second electrode 51 which is symmetrical about the longitudinal axis X—X of electrode 50 and is provided with a recess 52 formed in surface 53 thereof, the walls of recess 52 defining a segment of a sphere, each portion of which is disposed at an equal distance from the tip 55 of electrode 50. A centrally located opening 54 extends longitudinally through electrode 51 and is in communication with recess 52. It should be noted that opening 54 may contain a suitable dielectric substance such as plastic instead of being open wherein the atmosphere serves as a dielectric substance. The outline of the corona area is indicated by dotted lines 56. In a typical installation, the walls of recess 52 may be spaced 0.375 inch from tip 55 of electrode 50, and opening 54 may have a diameter of 0.50 inch. In a construction as shown in Fig. 4, it is apparent that the second electrode 51 provides a substantially greater collecting area at a constant distance from the emitting area than the previously disclosed modifications whereby the amount of current flow before an arc is produced is appreciably higher than that of other configurations.

Fig. 5 illustrates another modification wherein the first electrode 60 is identical with electrode 10 of the device shown in Fig. 1 and the second electrode 61 is symmetrical about the longitudinal axis X—X of electrode 60. An opening 62 is provided longitudinally through the center of electrode 61 and the end 63 of the electrode is tapered to a sharp edge 64 adjacent electrode 60. The outline of the corona area is illustrated generally by dotted lines 65. The sharp edge 64 of second electrode 61 provides an increase in the efficiency of operation of the device because of the fact that a positive corona is produced about the sharp edge in addition to the negative corona created about the emission area of the first electrode 60. In a typical configuration, electrode 61 may have a longitudinal dimension of 0.50 inch and the tapered portion 63 of the electrode may have a longitudinal dimension of 0.125 inch. Edge 64 is preferably spaced 0.375 inch from the tip 65 of electrode 60, and the diameter of opening 62 may also be 0.375 inch.

The operating characteristics of the diode device shown in Fig. 5 are illustrated in Fig. 6 wherein the second electrode voltage is plotted versus second electrode current. It can be seen that with a change of approximately 3,500 volts in the second electrode voltage between the value of 6,000 and 9,500 volts the second electrode current varies from approximately 10 to 600 micro-amperes. It is also apparent that the variation in second electrode current in accordance with changes in second electrode voltage is substantially linear over a large portion of curve 70.

Each of the modifications has been disclosed as adapted for operation in atmosphere, but each may also be satisfactorily operated in various gaseous media or in a partially evacuated envelope if desired. Only a few of the many possible configurations of the first and second electrodes have been disclosed, but in general it is preferred to have a first electrode which is either of extremely small diameter or which has a tapered emitting portion. The second electrode should be provided with a central portion formed of a suitable dielectric substance which is substantially aligned with the longitudinal axis of the first electrode, and as disclosed, this may be accomplished by providing an opening through the second electrode. The second electrode should also have a collecting area

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which is substantially greater than the emitting area of the first electrode such that a suitable corona is produced.

The dimensions of the first and second electrodes as disclosed indicate the relative size of the electrodes but it is emphasized that they may be made considerably larger or smaller if desired. Furthermore, the spacing and dimensions of the electrodes may be selected within wide limits in accordance with well-known design considerations. In each particular configuration of the first and second electrodes, the D. C. voltage required to produce ion flow will vary, and accordingly the D. C. operating potentials in each case must be chosen such that the operating potentials do not exceed the arcing potential for any particular configuration. It is also pointed out that, if desired, a plurality of units such as disclosed in the various modifications of the instant disclosure may be employed in parallel with one another, thereby increasing the volume output of the device.

The circuit shown in Fig. 2 is merely illustrative of the type of circuit which may be employed with the diode device and it is apparent that various other circuits may be employed therewith by one skilled in the art. In addition, it should also be noted that since the current output of the diode device changes as the distance between the two electrodes of the device when subjected to a constant D. C. bias, the distance between the two electrodes may be varied in accordance with an input signal, thereby producing the desired result. Of course, such a system would require an electromagnetic device for moving the first electrode. When used as a loud-speaker the mass of the dynamically moving first electrode is extremely small in comparison to the large cones and diaphragms employed in conventional speakers, the operating characteristics of such a system would be far superior to those of conventional speakers, yet is not considered as desirable as merely varying the D. C. potential between the electrodes, because it would introduce a small form of mass motion due to the first electrode mass.

Although in the previous discussion the ionic diode device has been disclosed as being utilized as a loud-speaker, it is important to note that various other applications of the device are possible. For example, the ionic diode device may be employed as a pressure gauge by enclosing the first and second electrodes within an enclosed chamber and introducing a pressure to be measured within the enclosed chamber. Such a pressure measuring device is maintained at a constant D. C. potential and the output current thereof is an inverse function of the pressure within the chamber and surrounding the electrodes. The output current of such a pressure gauge may be measured by a current measuring device such as a conventional milliammeter, thereby providing a direct reading of the pressure present within the enclosed chamber.

Various other applications of the diode device will become apparent to those skilled in the art.

It is evident from the foregoing that there is provided a new and novel ionic diode device which is especially adapted for use as a loud-speaker. The device is adapted to operate in atmosphere and has no moving parts. When operating as a loud-speaker it has no resonant frequencies and has a flat response within the audio range. The device is simple and inexpensive in construction, yet sensitive and reliable in operation.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

We claim:

1. An ionic diode device which comprises a first electrode composed of an electrically conductive substance and including an emitting portion, a second electrode spaced from said first electrode and being composed of an electrically conductive substance, an ionizable dielectric

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filling the space between said electrodes and means for impressing a D. C. potential across said first and second electrodes, said potential being lower than arcing potential and being of such polarity that said first electrode is negative with respect to said second electrode, thereby to create a region of intense ion flow in the space between said first and second electrodes.

2. A device as defined in claim 1 further including means for varying said D. C. potential.

3. An ionic diode device which comprises a first electrode composed of an electrically conductive substance and including an elongated emitting portion having an emitting area and a longitudinal axis, a second electrode spaced from said first electrode and being composed of an electrically conductive substance, said second electrode having a collecting area substantially large than said emitting area, said second electrode having an opening formed therethrough, said opening being substantially aligned with said longitudinal axis, a gaseous dielectric filling the space between said electrodes, and means for impressing a D. C. potential across said first and second electrodes to ionize said dielectric, said potential being lower than arcing potential and being of such polarity that said first electrode is negative with respect to said second electrode.

4. A device as defined in claim 3 further including means for varying said D. C. potential.

5. A device as defined in claim 3 wherein said elongated emitting portion of said first electrode has a tapered outer configuration.

6. An ionic diode device which comprises a first electrode composed of an electrically conductive substance and including an elongated emitting portion having a longitudinal axis, a second electrode spaced from said first electrode and being composed of an electrically conductive substance, said second electrode having a substantially annular configuration and being disposed substantially symmetrically about said longitudinal axis, said second electrode lying in a plane which is substantially normal to said longitudinal axis, and means for impressing a D. C. potential across said first and second electrodes, said potential being lower than arcing potential and being of such polarity that said first electrode is negative with respect to said second electrode.

7. A device as defined in claim 6 including means for varying said D. C. potential.

8. An ionic diode device which comprises a first electrode composed of an electrically conductive substance and including an elongated emitting portion having an outer end and a longitudinal axis, a second electrode spaced from said first electrode and being composed of an electrically conductive substance, said second electrode having a recess formed therein defining a segment of a sphere, the walls of said recess being spaced at a substantially constant distance from the end of said emitting portion, a dielectric substance substantially aligned with said longitudinal axis, said second electrode being disposed about said dielectric substance, and means for impressing a D. C. potential across said first and second electrodes, said potential being lower than arcing potential and being of such polarity that said first electrode is negative with respect to said second electrode.

9. A device as defined in claim 8 including means for varying said D. C. potential.

10. An ionic diode device which comprises a first electrode composed of an electrically conductive substance and including an elongated emitting portion having an outer end and a longitudinal axis, a second electrode spaced from said first electrode and being composed of an electrically conductive substance, said electrode having a recess formed therein defining a segment of a sphere,

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the walls of said recess being spaced at a substantially constant distance from the end of said emitting portion, said second electrode having an opening formed therethrough which is in communication with said recess, said opening being substantially aligned with said longitudinal axis, and means for impressing a D. C. potential across said first and second electrodes, said potential being lower than arcing potential and being of such polarity that said first electrode is negative with respect to said second electrode.

11. A device as defined in claim 8 including means for varying said D. C. potential.

12. An ionic diode device designed to operate in an ionizable medium which comprises a first electrode composed of an electrically conductive substance and including an elongated emitting portion having a longitudinal axis, a second electrode spaced from said first electrode and being composed of an electrically conductive substance, said second electrode having a tapered edge formed on one end portion thereof, a dielectric substance substantially aligned with said longitudinal axis, said second electrode being disposed about said dielectric substance, and means for impressing a D. C. potential across said first and second electrodes, said potential being lower than arcing potential and being of such polarity that said first electrode is negative with respect to said second electrode.

13. A device as defined in claim 12 further including means for varying said D. C. potential.

14. An ionic diode device designed to operate in an ionizable medium which comprises a first electrode composed of an electrically conductive substance and including an elongated emitting portion having a longitudinal axis, a second electrode spaced from said first electrode and being composed of an electrically conductive substance, said second electrode having a tapered edge formed on one end portion thereof, said second electrode having an opening formed therethrough, said opening being substantially aligned with said longitudinal axis, and means for impressing a D. C. potential across said first and second electrodes, said potential being lower than arcing potential and being of such polarity that said first electrode is negative with respect to said second electrode.

15. A device as defined in claim 14 further including means for varying said D. C. potential.

16. An ionic diode device which comprises a first electrode composed of an electrically conductive substance and including an elongated emitting portion having a longitudinal axis, a second electrode spaced from said first electrode and being composed of an electrically conductive substance, said second electrode being formed as a plate lying in a plane substantially normal to the said longitudinal axis, a gaseous dielectric filling the space between said electrodes, and means for impressing a D. C. potential across said first and second electrodes to ionize said dielectric, said potential being lower than arcing potential and of such polarity that said first electrode is negative with respect to said second electrode.

17. A device as defined in claim 16 further including means for varying said D. C. potential.

18. A device defined in claim 16 wherein said second electrode has an opening formed therethrough which is aligned without said longitudinal axis, and a dielectric substance at least partially filling said opening.

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