May 21, 1957 M. N. HALUS ET AL 2,793,324

IONIC TRIODE SPEAKER

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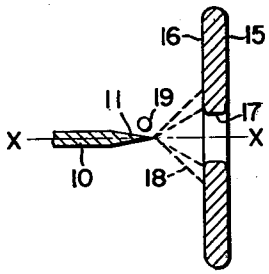


Fig. 1

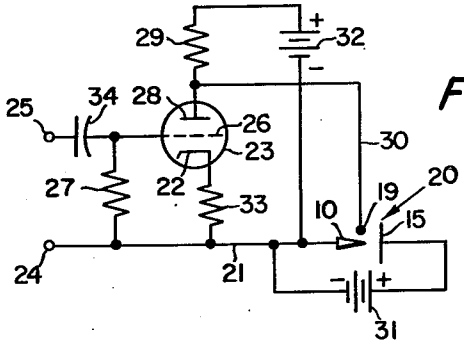


Fig. 2

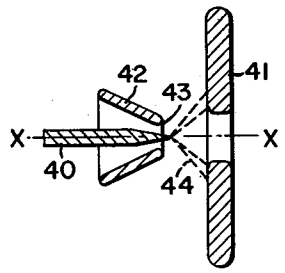


Fig. 3

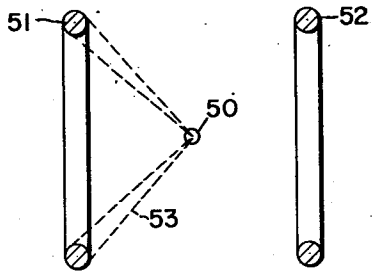


Fig. 4

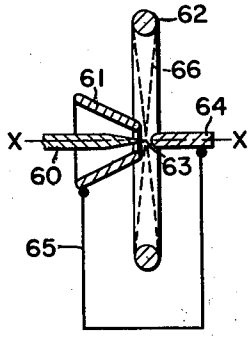


Fig. 5

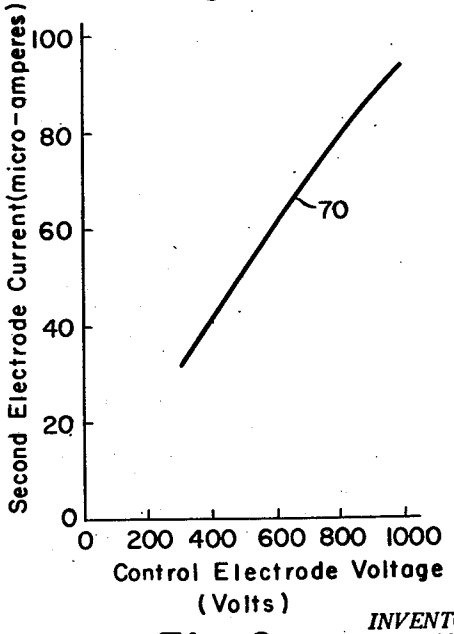


Fig. 6

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IONIC TRIODE SPEAKER

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11 Claims. (Cl. 315—168)

(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 new and novel ionic triode device and more particularly to an ionic triode device wherein an ion flow is established between first and second electrodes and a control electrode is provided for controlling the ion flow between the first and second electrodes to accomplish the purposes of the invention.

The present application is closely related to our concurrently-filed application, Serial Number 606,784 entitled "Ionic Diode Device" which discloses a device wherein only two electrodes are utilized. The present invention employs three electrodes having a novel relationship to one another which provides certain advantages over the device disclosed in our co-pending application.

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 than an ion flow between the electrodes is produced, resulting in corona. The ion flow between the first and second electrodes may be controlled by means of a third control electrode spaced from and positioned closely adjacent the emitting area of the elongated electrode. A D. C. potential is impressed across the first and third electrodes and by varying this potential, the ion flow between the first and second electrodes may be modulated. It is emphasized that the D. C. potential between the first and second electrodes 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.

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 gaseous media, and the magnitude of the electric 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 electrides. 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 a narc.

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 of 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 reproduction purposes.

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 biased 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. The potential impressed across the first elongated electrode and the third or control electrode is adjusted

such that the control voltage is biased to the midpoint of the linear static curve obtained when the third electrode voltage is plotted versus the second electrode current. Upon applying a modulating peak-to-peak voltage within the static range, a directly proportional ionic flow is obtained between the first and second electrodes which in turn causes a release of energies that result in audible sound. The sound produced is consequently a faithful reproduction of the 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.

The analogy and differences between the present invention and a conventional vacuum tube triode should be noted. As in the case of a conventional vacuum tube triode, three electrodes are provided with the first elongated electrode of the present invention corresponding to the cathode of a vacuum tube, the second electrode of the present invention corresponding to the plate of a vacuum tube, and the third or control electrode of the present invention corresponding to the grid of a vacuum tube. At this point the analogy between the two types of devices ends. Devices according to the present invention operate in atmosphere wheareas conventional vacuum tubes cannot properly function in such an environment and must either be provided with an evacuated envelope or an envelope containing various rare gases in accordance with the function of the tube. In addition, a bias voltage is impressed between the first and second electrodes in the present invention whereby ionization is produced largely by collision and partly by photoelectric effect in contrast to the thermionic emission which is utilized in conventional vacuum tubes. A further important distinction of the present invention from the constructions incorporated in conventional vacuum tubes lies in the fact that the control electrode in the present invention must of necessity be disposed outside the area of corona or intense ion flow, whereas in conventional vacuum tubes it is essential that the grids thereof be disposed directly in the path of electron flow between the cathode and plate in order to control such electron flow. It is accordingly apparent that there are a number of important structural and functional distinctions between the construction and operation of the present invention and that of conventional vacuum tubes.

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

Another object is to provide a new and novel loudspeaker 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 triode 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 triode 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; and

Fig. 6 is a graph illustrating the control electrode voltage versus second electrode current 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 metallic 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 transmitted 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. Electrode 15 may also be formed as a solid plate, if desired, and satisfactory operation may be obtained although it does not operate as efficiently when used as a loud-speaker. In a typical construction of the device shown in Fig. 1, electrode 10 may have a diameter of 0.037 inch at the root 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 provided only for the purpose of illustration and should not be construed as critical or restrictive.

In addition to the first and second electrodes 10 and 15, a third electrode 19 formed of a suitable electrically conductive substance such as steel is provided, and in this case comprises a thin wire of approximately 0.0625 inch diameter extending substantially normal to the plane of the drawing, spaced from but positioned closely adjacent to the emitting area of electrode 10. The emitting area of elongated electrode 10 is concentrated substantially at the outer tip thereof but extends slightly back along the tapered surface of the outer end of the electrode. In order to accomplish the purposes of the invention and to properly control the ion flow between the first and second electrodes 10 and 15, it is essential that the control electrode 19 be positioned outside of the area of intense ion flow. Since the area of intense ion flow, as indicated by dotted lines 18, extends from the outer tip of electrode 10 to electrode 15 it is evident that control electrode 19 should be positioned rearwardly of the outer tip of electrode 10 to obtain satisfactory results; and

for example, the distance parallel to axis X—X between the outer tip of electrode 10 and the center of control electrode 19 may be 0.042 inch.

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 triode device is connected by lead 21 through bias resistor 33 to the cathode 22 of conventional triode 23 and is also connected to input terminal 24. The opposite input terminal 25 is connected through capacitor 34 to the grid 26 of tube 23, and resistor 27 provides the grid return in a conventional manner. The plate 28 of triode 23 is connected to a low voltage B+ source 32 through resistor 29. Plate 28 is also connected by means of lead 30 to the control electrode 19 of the ionic triode device. The second electrode 15 of the ionic triode device is connected to the positive terminal of a suitable source of D. C. potential such as a battery 31, and electrode 10 is connected to the negative terminal of source 31. Battery 31 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, characteristics of the ionic triode device will vary, and accordingly the D. C. bias must be chosen for the particular configuration and dimensions employed in any given application. The D. C. potential applied to control electrode 19 through resistor 29 is selected such that electrode 19 is biased to the midpoint of the linear static curve wherein the control electrode voltage is plotted versus the second electrode current.

An A. C. control signal is impressed across input terminals 24 and 25 of the circuit shown in Fig. 2 during operation. Current flow through tube 23 is accordingly varied such that the potential upon control electrode 19 is varied. Upon a change in the potential upon electrode 19, the ionic flow between electrodes 10 and 15 is correspondingly altered, thereby producing sound such that triode device 20 serves as a loud-speaker which faithfully reproduces the signal impressed upon input terminals 24 and 25.

In each of the modifications disclosed hereinafter, the first electrode corresponds to electrode 10 of the device shown in Fig. 1, the second electrode corresponds to electrode 15 of the device shown in Fig. 1, and the third or control electrode corresponds to electrode 19 of the device shown in Fig. 1. It is evident that the first, second and third 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, 15, and 19 are connected, with corresponding results.

Fig. 3 illustrates a modification wherein a first electrode 40 thereof is identical with electrode 10 of Fig. 1 and the second electrode 41 is identical with electrode 15 of Fig. 1. The control electrode 42 is hollow and has a substantially conical configuration, electrode 42 surrounding electrode 40 and being disposed symmetrically about the axis X—X of the elongated electrode. The inner diameter of the opening formed at the smaller opening formed at the right hand end of control electrode 42 may be 0.040 inch and the outer end 43 of control electrode 42 is spaced 0.003 inch longitudinally behind the outer tip of elongated electrode 40. The corona area generated between electrodes 40 and 41 is generally conical in configuration and is indicated by dotted lines 44 in Fig. 3. It should be noted that control electrode 42 is disposed outside the area of intense ion flow.

Fig. 4 illustrates a modification wherein a first electrode 50 is identical with electrode 10 of the device shown in Fig. 1 and is disposed normal to the plane of the drawing with the outer tip of the elongated electrode being disposed in the plane of the drawing. A second electrode 51 has a substantially annular configuration and lies in a plane parallel to the longitudinal axis of electrode 50, the outer tip of electrode 50 being disposed in a plane passing diametrically through annular electrode 51. A control electrode 52 is disposed in parallel relationship to electrode 51 on the opposite side of the elongated electrode 50. The corona area between elongated electrode 50 and the second electrode 51 is generally conical in configuration as indicated by dotted lines 53 in Fig. 4 and it is evident that control electrode 52 is disposed outside of the area of intense ion flow. Electrodes 51 and 52 may be identical in construction and the cross-sectional diameter of the bodies of each of annular electrodes 51 and 52 may be 0.187 inch and the diameter of the inner hollow portion of electrodes 51 and 52 may be 0.782 inch.

Fig. 5 illustrates a modification wherein a first electrode 60 is identical with electrode 40 of the device shown in Fig. 3 and is surrounded by a control electrode 61 identical with control electrode 42 of the device shown in Fig. 3. A second electrode 62 is identical with electrode 51 of the device shown in Fig. 4 and is disposed radially outward of the outer tip 63 of elongated electrode 60. Another control electrode 64, having an elongated configuration, is substantially aligned with the longitudinal axis X—X of elongated electrode 60 and may be spaced 0.0625 inch from the outer right hand end of electrode 61 when dimensions such as disclosed in Fig. 3 are utilized for electrodes 60 and 61. Control electrodes 61 and 64 are electrically connected to one another by lead 65. The corona area extends substantially radially outward from tip 63 of electrode 60 as indicated by dotted lines 66 and it is evident that each of control electrodes 61 and 64 are disposed outside the area of intense ion flow.

The operating characteristics of the triode device shown in Fig. 5 are illustrated in Fig. 6 wherein the control electrode voltage is plotted versus the second electrode current. It can be seen that with a change of approximately 700 volts in the control electrode voltage between the values of 300 and 1,000 volts, the second electrode current varies approximately 65 micro-amperes between the values of 30 and 95 micro-amperes. It is also apparent that the variation in the second electrode current in accordance with changes in control 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, second and control 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 may 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 have a collecting area which is substantially greater than the emitting area of the first electrode such that a suitable corona is produced. The control electrode must be spaced from the first electrode in each case positioned adjacent to the emitting portion of the first electrode and disposed outside of the area of intense ion flow between the first and second electrodes.

The dimensions of each of the electrodes as disclosed indicate the relative size of the electrodes but it should be 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 elements 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.

It is evident from the foregoing that there is provided a new and novel ionic triode device 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 triode 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, 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 between said first and second electrodes, a third electrode spaced from said first and second electrodes and being disposed outside of said region of ion flow, and means for impressing a control signal across said first and third electrodes.

2. An ionic triode 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 larger than said emitting area, said second electrode having an opening formed therein, said opening being substantially aligned with said longitudinal axis, 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 between said first and second electrodes, a third electrode spaced from said first and second electrodes and being disposed outside of said region of ion flow, and means for impressing a control signal across said first and third electrodes.

3. A device as defined in claim 2 wherein said elongated emitting portion of said first electrode has a tapered outer configuration.

4. An ionic triode 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, 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 establish a region of intense ion flow between said first and second electrodes, a third electrode comprising a wire spaced from and closely adjacent to said emitting portion, said third electrode being disposed outside of said region of ion flow, and means for impressing a control signal across said first and third electrodes.

5. A device as defined in claim 4 wherein said second electrode has an opening formed therein, said opening being substantially aligned with said longitudinal axis.

6. An ionic triode 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 larger than said emitting area, a dielectric substance substantially aligned with said longitudinal axis, said second electrode being disposed about said dielectric substance, 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 establish a region of intense ion flow between said first and second electrodes, a third electrode comprising a wire spaced from and closely adjacent to said emitting portion, said third electrode being disposed outside of said region of ion flow, and means for impressing a control signal across said first and third electrodes.

7. An ionic triode 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, 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 between said first and second electrodes, a third hollow electrode having a substantially conical configuration spaced from and surrounding said first electrode adjacent the emitting portion thereof, said third electrode being disposed substantially symmetrically about said longitudinal axis and being outside of said region of ion flow, and means for impressing a control signal across first and third electrodes.

8. A device as defined in claim 7 wherein said second electrode has an opening formed therein, said opening being substantially aligned with said longitudinal axis.

9. An ionic triode 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 larger than said emitting area, a dielectric substance substantially aligned with said longitudinal axis, said second electrode being disposed about said dielectric substance, 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 between said first and second electrodes, a third hollow electrode having a substantially conical configuration spaced from and surrounding said first electrode adjacent the emitting portion thereof, said third electrode being disposed substantially symmetrically about said longitudinal axis and being outside of said region of ion flow, and means for impressing a control signal across first and third electrodes.

10. An ionic triode 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, said second electrode having a substantially annular configuration, 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 establish a region of intense ion flow between said first and second electrodes, a third electrode spaced from the first electrode and having a substantially annular configuration, said third electrode being disposed outside

of said region of ion flow, and means for impressing a control signal across said first and third electrodes.

11. An ionic triode 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 the first electrode and having a substantially annular configuration, said second electrode being composed of an electrically conductive substance, 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 first electrode is negative with respect to said second electrode, thereby to establish a region of intense ion flow between said first and second electrodes, a third hollow electrode having a substantially conical configuration spaced from and surrounding said first electrode adjacent said emitting portion, said third electrode being disposed substantially symmetrically about said longitudinal axis, a fourth elongated electrode having a longitudinal axis which is substantially aligned with the longitudinal axis of said first electrode, each of said third and fourth electrodes being disposed outside of said region of ion flow, said third and fourth electrodes being electrically connected to one another, and means for impressing a control signal across said first electrode and said third and fourth electrodes.

No references cited.