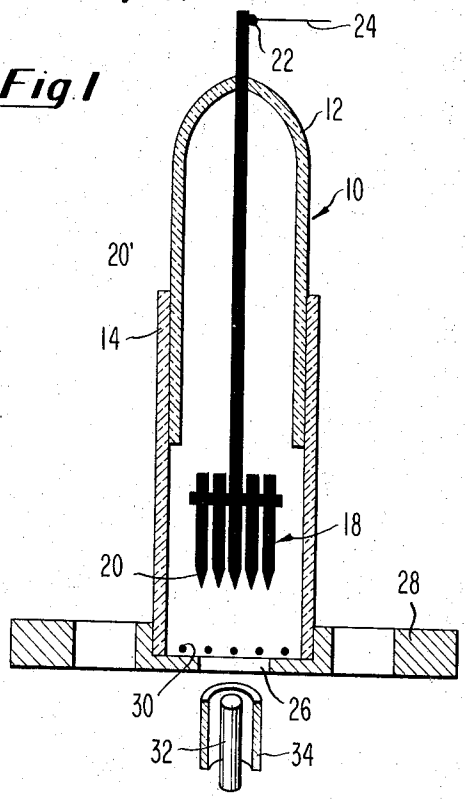
Dec. 12, 1967 PO LEE 3,358,289

ELECTROSTATIC TRANSDUCER APPARATUS

Filed May 23, 1963 5 Sheets-Sheet 1

Fig. 1



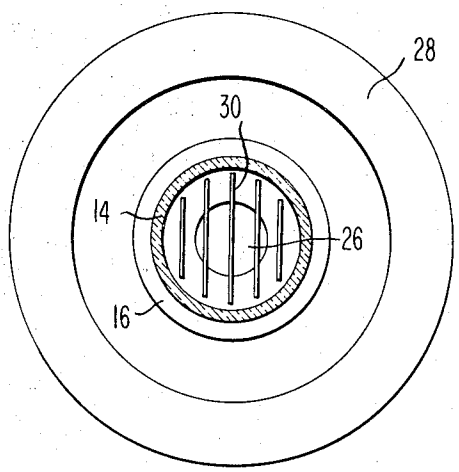


Fig. 2

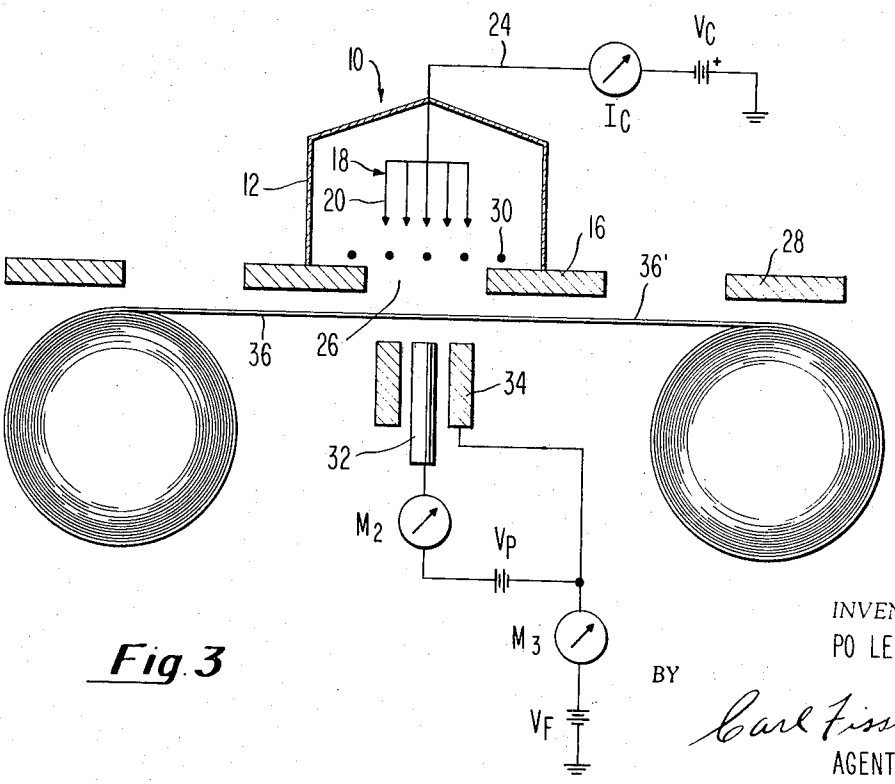


Fig. 3

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ELECTROSTATIC TRANSDUCER APPARATUS

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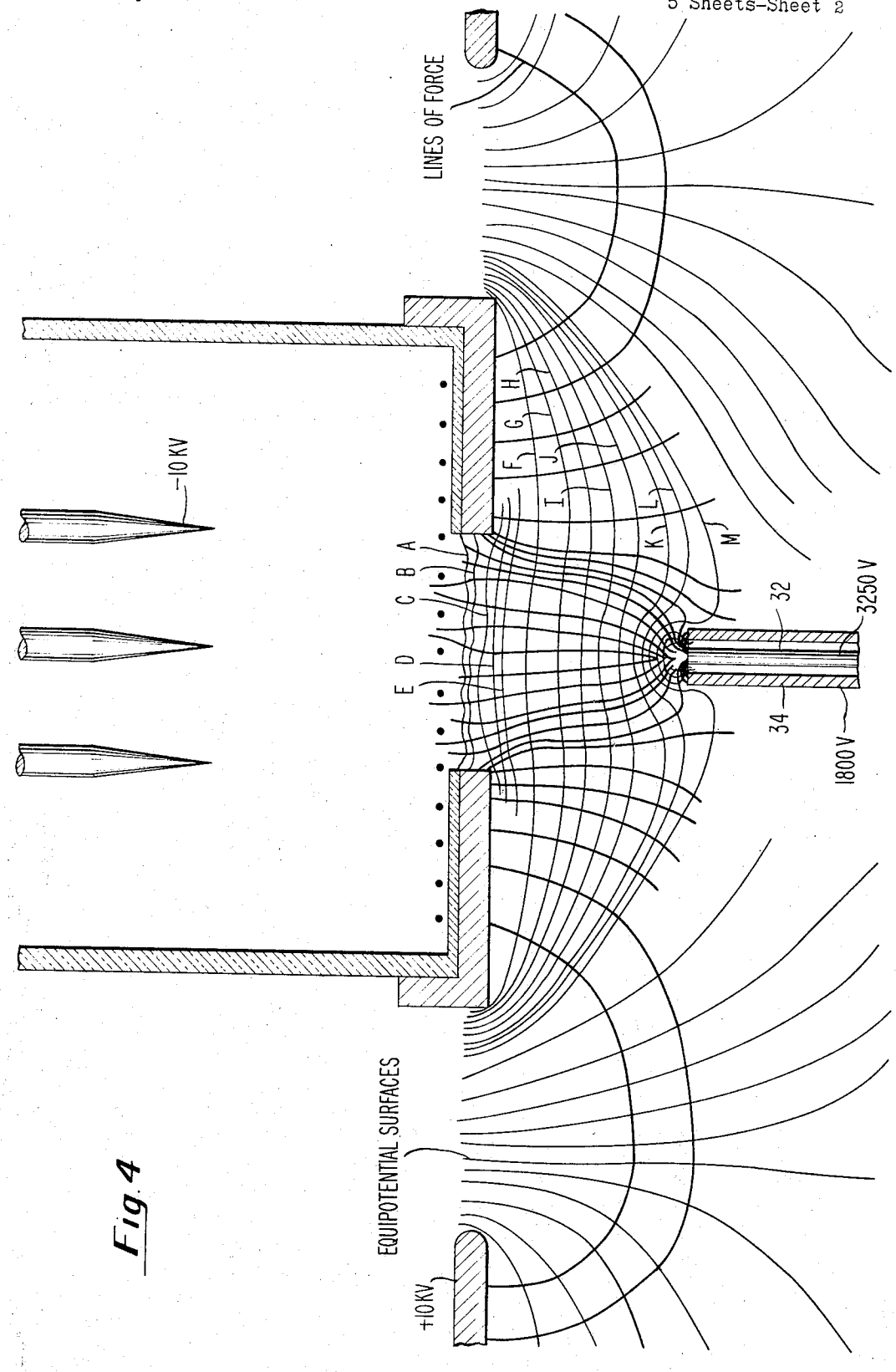


Fig. 4

ELECTROSTATIC TRANSDUCER APPARATUS

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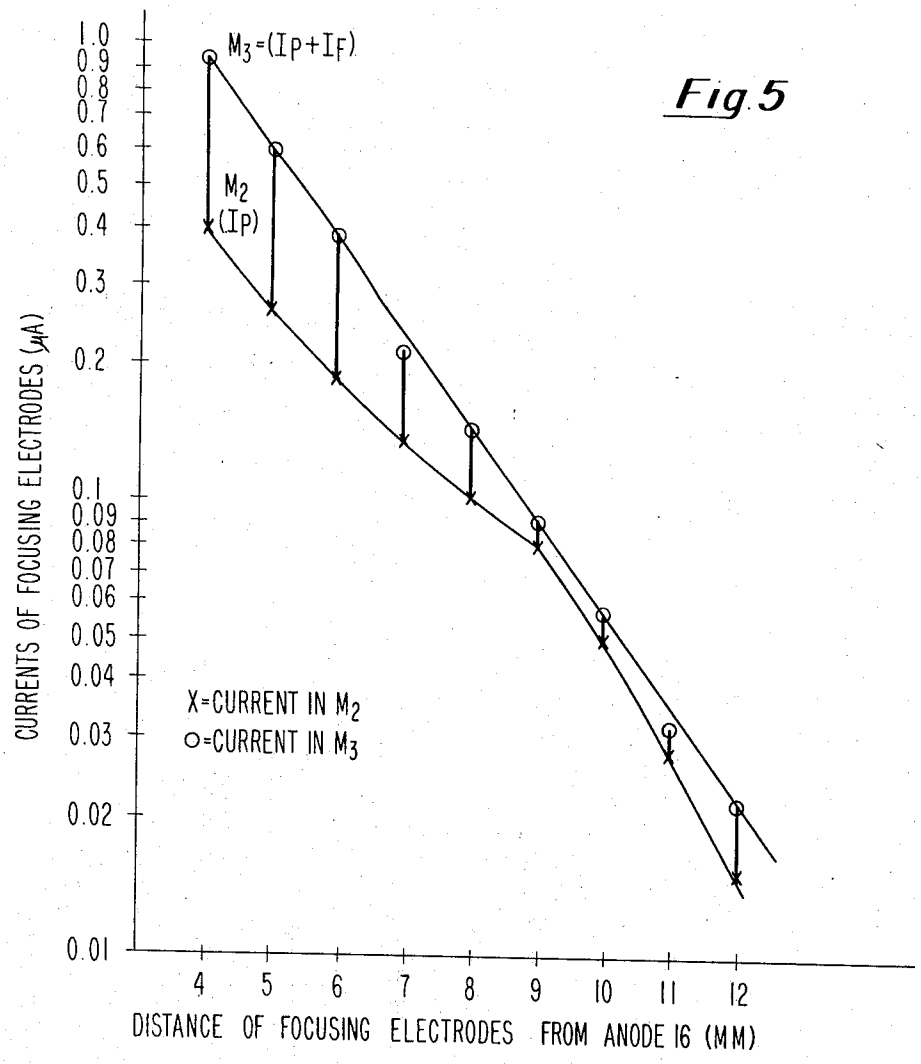


Fig. 5

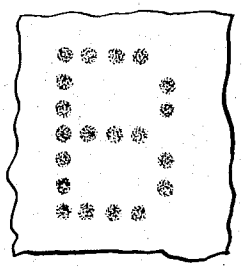


Fig. 10

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ELECTROSTATIC TRANSDUCER APPARATUS

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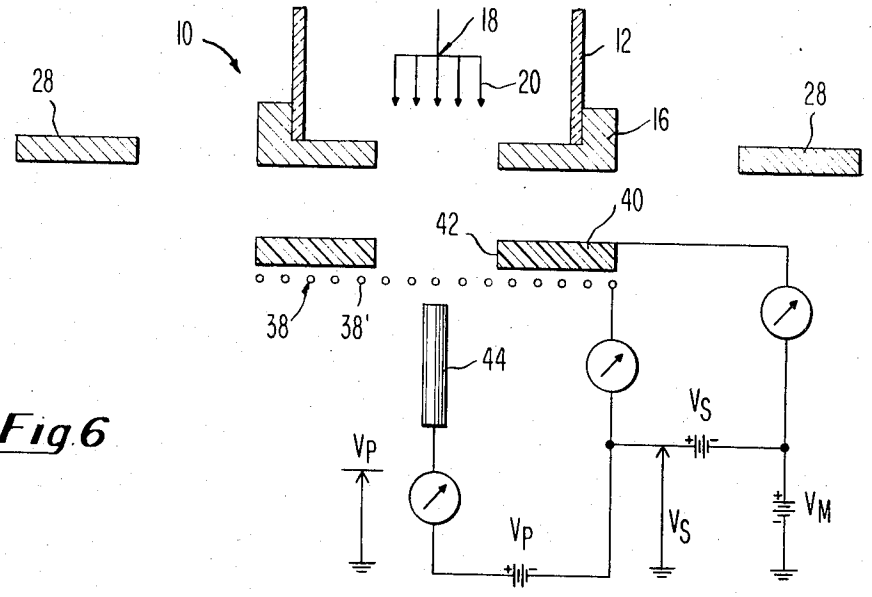


Fig. 6

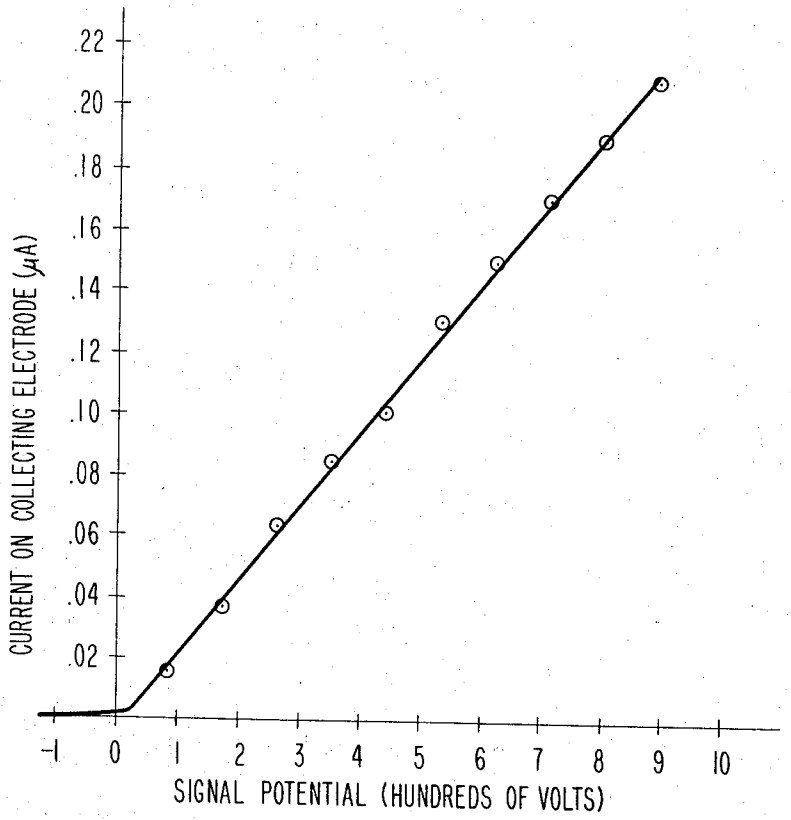


Fig. 7

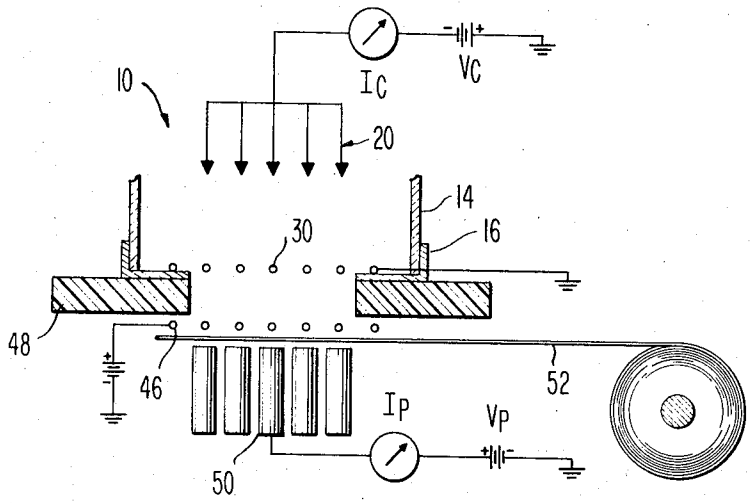
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ELECTROSTATIC TRANSDUCER APPARATUS

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Fig. 8



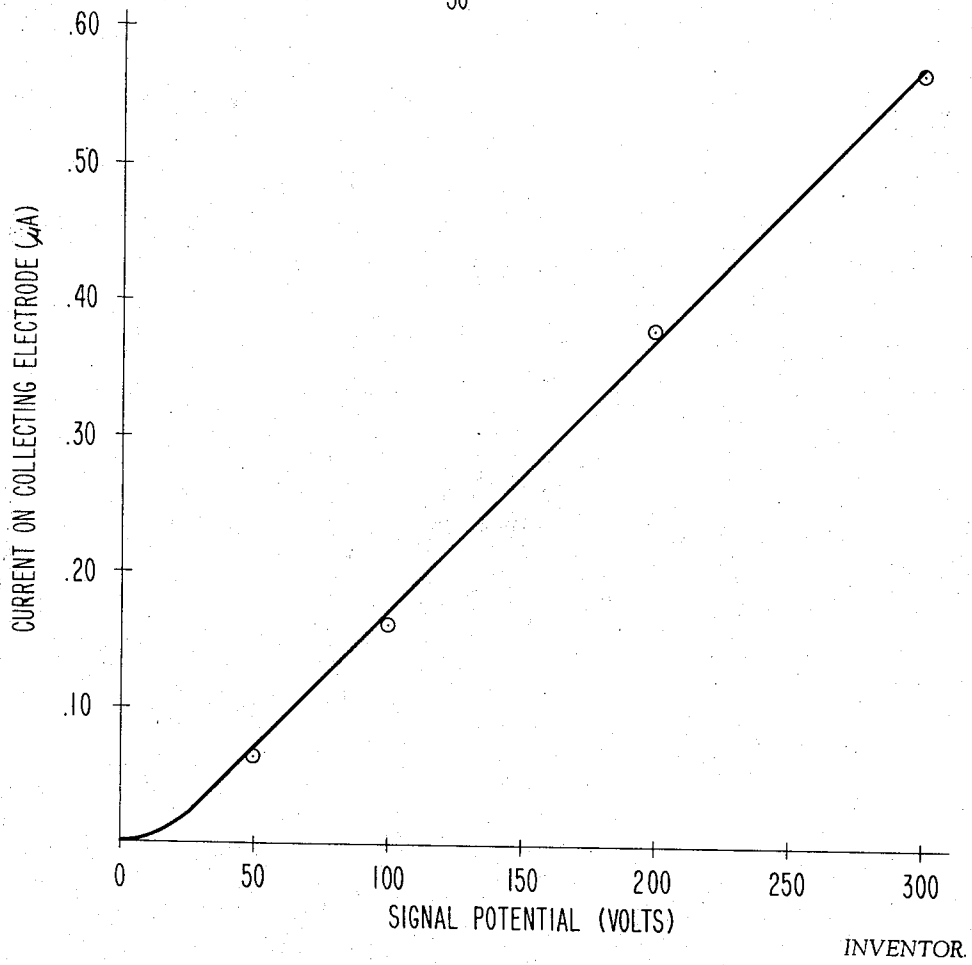


Fig. 9

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ELECTROSTATIC TRANSDUCER APPARATUS

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Filed May 23, 1963, Ser. No. 282,728
15 Claims. (Cl. 346—74)

ABSTRACT OF THE DISCLOSURE

This invention relates to electrostatic transducer apparatus including a corona discharge device for generating positive or negative ions in atmospheric air is operably associated with electrode members for shaping the electrostatic field and focusing the ions generated by the corona discharge into a beam. One or more signal responsive members located at the focus of the ion beam and operably associated with one or more grid-like members are adapted to modulate the ion beam effective to produce intelligible recordings on record media arranged to move between the corona discharge generator and the signal responsive member or members. A focusing shield may be employed with the signal responsive member to aid in focusing the ion beam onto the signal member.

This invention relates to electrostatic transducer apparatus and more particularly, although not necessarily exclusively, to means providing a controlled source of ions for utilization in electrostatic printing. With still more particularity, the invention relates to a novel ion generator and focusing mechanism for generating, controlling and focusing a corona discharge between two electrodes in a manner thereby to produce a well defined spot on a dielectric record member. With still further particularity, the invention has to do with high speed electrostatic marking apparatus wherein ions are brought into a sharply focused spot on a dielectric surface effectively permitting the apparatus to be employed as a transducer for electrostatic printing as well as for dielectric tape recording and/or memory storage devices.

It is an important object of the present invention therefore to provide an ion source which is operable in atmospheric air for producing an electrostatic charge spot on a record medium.

Another object of the invention is to provide corona discharge apparatus with means for modulating the electrostatic discharge so as to produce intelligence upon a record medium.

Still another object of the invention is to provide electrostatic corona discharge apparatus with means for focusing ions generated thereby into a well defined spot on a record medium.

A still further object of the invention is the provision of electrostatic transducer apparatus in which printing action is independent of the surface condition of the printing electrodes.

It is also an object of the present invention to provide electrostatic corona discharge apparatus wherein the size of the printed spot is a function of the field of the focusing electrode and is controlled thereby.

Another important object of this invention is the provision of electrostatic transducer apparatus which overcomes the corrosion problem associated with certain types of electrostatic printing devices.

In accordance with the foregoing objects and first briefly described, the present invention comprises one or more discharge pin-like electrodes disposed adjacent and normal to a substantially planar electrode in a manner such that a high potential difference can be maintained on these electrodes effective to produce a corona discharge between the planar electrode and the pin electrodes. A high potential electrode for producing a sharply defined electrostatic field effective to pull ions out of the corona gap is disposed adjacent the planar electrode. A secondary electrode operably associated with a printing electrode on which a control signal is applied, is arranged adjacent to and spaced apart from the corona discharge electrodes in a manner effective to focus ions produced thereby into a sharp spot on an associated record member for electrostatic printing and for dielectric tape sound recording.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of the preferred embodiment of the invention, as illustrated in the accompanying drawings, wherein the various figures represent diagrammatic views of transducer apparatus embodying the invention.

In the figures:

FIG. 1 is a sectional view through a preferred embodiment of apparatus utilizing the present apparatus;

FIG. 2 is a top plan view of the structure of FIG. 1;

FIG. 3 is a schematic illustration of electrostatic recording apparatus embodying the invention;

FIG. 4 is an idealized diagram of an electric field configuration for the device of FIG. 1;

FIG. 5 is a chart illustrating the focusing characteristics versus applied current for the apparatus of FIG. 3;

FIG. 6 is an idealized schematic diagram of a modified form of transducer apparatus embodying the invention;

FIG. 7 is a chart illustrating the I–V characteristics of the apparatus of FIG. 6;

FIG. 8 is an idealized schematic diagram of a further modification of the apparatus embodying the invention;

FIG. 9 is a chart illustrating the I–V characteristic of the apparatus of FIG. 8, and

FIG. 10 is a greatly enlarged view of a letter B formed by means of this invention.

In an electrical system including an anode and a cathode in which a potential difference exists therebetween, when a divergent electric field existing around the anode in air is high enough, a local breakdown takes place. Electron avalanches photoelectrons, and electric field distortions produce a burst corona discharge. Electrons in the burst corona rush to the anode and positive ions drift away from the high field region towards the cathode. It is possible as will be described hereinafter, to draw these positive ions out of the corona gap (between the cathode and anode) by an external electrical field.

Near the cathode the high convergent electric field causes secondary emissions from this positive ion bombardment to develop electron avalanches and local cathode breakdown. Due to their relatively low drift velocity, a positive space charge forms around the cathode which limits the negative corona discharge in a periodic manner. In the negative corona discharge at the cathode the positive ions rush to the cathode. Released electrons drift toward the low field region and become attached to oxygen molecules in air to form an O_2^- molecular ion. It is possible to cause the O_2^- ions to drift from the corona gap by application of an external electrostatic field.

If the anode and cathode are arranged so that a very low electric field region exists between them, yet high field conditions are present at the electrodes, then the anode streamer formed thereby cannot cross the gap and spark discharge cannot occur. Thus, a steady corona discharge provides a source of positive and negative ions.

A point to plane corona ion source, as hereinafter described, is capable of generating negative ions in air. This apparatus can also be used to produce positive ions by the simple expedient of changing the sign of the applied po-

tentials on the electrodes. Suitable geometry, as hereinafter described, is effective to focus, modulate and otherwise control the ion source.

A preferred form of the present invention is seen in FIG. 1 as embodied in corona discharge transducer apparatus **10** and includes a transparent bell-like member **12** through which the corona discharge readily can be observed. The member **12** may be slidably, adjustably received in a cylindrical member **14**, the latter being fixed to and projecting vertically from a base discharge (anode) electrode **16**, in a known manner. The member **12** may have integral therewith or carry a (cathode) electrode assembly **18**, including a plurality of needle or pin-like electrodes **20** extending from one end thereof. The central electrode **20'** extends outwardly through the curved top portion of member **12** thereby providing a terminal **22** for attachment thereto of the high voltage lead **24** from a suitable source of high voltage not shown in this figure.

The base discharge (anode) electrode **16**, which may be annular or ring-shaped, as seen in FIG. 2, is provided with a central annular opening **26**, for purposes to be explained presently. A focusing (anode) electrode **28**, also ring-shaped, is disposed adjacent and concentric with the discharge (anode) electrode **16** and is supported in spaced apart relation thereto in a known manner. A horizontal overlay of wires **30** is or may be disposed contiguous with the aperture **26**. A probe electrode **32** disposed within a focusing shield member **34** is arranged adjacent to and concentric with the aperture **26** and aids in focusing the field onto the probe **32**.

Application of suitable potentials, as hereinafter described, to the cathode lead **24** and the two anodes **16** and **28** produces an electric field configuration such as that shown in FIG. 4. The efficiency of the ion output, measured by the corona current, depends upon the electrical field near the discharge anode **16** and is controlled by the geometry of the electrodes and the potentials applied to them. The design of the cathode electrodes **20** is such as to make the volume of the high electric field in the region near the tips thereof as large as possible under the given applied potential, whereby the cathode tips can produce a large number of negative corona pulses. The field potential plot, FIG. 4, is shown with the calculated voltages (as set forth hereinbelow) applied to the equipotential surfaces, designated "*a*" through "*m*" respectively:

	Volts
a	−100
b	0
c	+100
d	200
e	300
f	500
g	800
h	1000
i	1200
j	1400
k	1600
l	1700
m	1800

The lines of force and equipotential surfaces are orthogonal as shown. Since the equipotential surfaces have negative curvatures, i.e., convex, toward the aperture **26**, ions are focused into a convergent beam. Such a field configuration is ideal for electrostatic recording since it is productive of high resolution in terms of spot size.

An operating structure fabricated in accordance with the teaching of the present invention includes a Pyrex bell jar **12** 25 mm. in diameter, 1 mm. thick disposed within a 28 mm. glass cylinder **14** also 1 mm. thick. The bell jar **12** carries a cathode assembly **18** including five 50 mil thick tungsten wires **20** with the tips ground to very sharp points and disposed in parallel spaced apart relation with each 7 mm. apart. The discharge electrode

(anode) **16** was three centimeters in diameter of 3/16 aluminum provided with a one centimeter I.D. opening **26** therein. The focusing electrode **28** was also 3/16 inch thick aluminum seven centimeters in diameter with a five centimeter I.D. opening therein thereby providing a one centimeter annular member.

A course wire screen or grid **30** was initially used (later abandoned as unnecessary) to smooth out the curvature of the equipotential surfaces near the center opening **26** and make them substantially flat. The distance between the cathode tips and the wire screen was one centimeter. The opening acting as an aperture for the ion source was 9.5 mm. I.D. The probe electrode **32** was 0.75 mm. in diameter while the shield electrode **34** was 2.77 mm. O.D. The separations between electrodes was 0.46 mm.

The performance of the ion source is exemplified by the data shown in the table below:

TABLE I.—OUTPUT ION CURRENT

Voltage between Corona Electrodes (Kilovolts)	Corona Current (Microamperes)	Output Ion Current (Microamperes)
5.0	18	.72
5.5	26	.78
6.0	35	.85
6.5	45	1.1
7.0	60	1.7
7.5	75	2.6
8.0	94	3.3
8.5	120	3.4

Potential on the focusing anode **28**=+10 kilovolts (with wire screen).

Experments were performed by removing the wire screen and covering the inside surface of the anode in the glass chamber by a piece of dielectric. The two sets of results are given in Table II*a* and Table II*b*. It is seen that when the inside surface of the anode is covered, the efficiency of the ion output increases rapidly. For a given geometry and potentials applied on the corona electrodes, the increase of the focusing anode potential would give a similar effect. An output current of 3 microamperes sufficiently large for electrostatic recording purposes, including electrostatic printing, has been obtained. Such an ion source can be used, as beforementioned, to supply negative or positive ions for any electrostatic recording purpose.

TABLE II*a*

No wire screen, inside anode surface partially covered with a piece of dielectric		
Voltage between Corona Electrodes (in kilovolts)	Corona Current (in microamperes)	Output Current (in microamperes)
5	4	1.2
6	6	1.5
7	8	2.0
8	14	2.5
8.5	18	2.7
9	32	2.9

TABLE II*b*

No wire screen, inside anode surface completely covered with a piece of dielectric		
Voltage between Corona Electrodes (in kilovolts)	Corona Current (in microamperes)	Output Current (in microamperes)
3.5	0.5	.3
4.0	1.0	.7
5.0	1.5	1.2
6.0	2.0	1.6
7.0	3.0	2.0
8.0	4.0	2.8
9.0	6.0	3.4

Potential on the focusing anode 28=10 kilovolts.

Referring now to FIG. 3, various potentials, as set forth hereinbelow, are applied to the elements of the apparatus in the manner shown:

V_p=3250 v.
V_F=1800 v.
V_A=+10 kv.
V_C=−10 kv.
IC=100μa.
Single mesh covering aperture 26
M_2, M_3 } Ammeters.

Experimentally the focusing electrodes 32 and 34 were placed at a series of different locations at varying distances from anode 16 and the currents measured by ammeters M_2 and M_3. The results as shown in FIG. 5 verify the focusing aspect of the device. The heavy vertical lines indicate the magnitude of the ion current at focus depth f_d. It is a minimum where focusing occurs (current on M_2=to current of M_3 at a distance of 9 millimeters from anode 16. Thus when the electrode 32 is placed at the focal point, all the ions go to that electrode.

Extrapolating from these curves, the estimated focal point at a distance of 9.2 millimeters from the surface of the anode 16 can be obtained. This is in agreement with the result obtained by field plotting. When the signal electrode 32 is placed at the focal point the ions are attracted to it in a sharply focused beam or spot.

A dielectric record medium 36, i.e., Mylar tape, etc. is arranged as shown in FIG. 3 and is caused to pass between the electrode 16 and electrodes 32 and 34 by means not shown. Energization of the electrical elements of the apparatus produces a corona discharge. The ion beam from this discharge strikes the dielectric surface 36' and the electric charges stick to the surface. A 1450 volt square wave pulse was used for V_p. The duration of the pulse was 500 microseconds. The cross section of the ion beam was registered at three different locations. These results are shown in the chart of Table III and verify the experimental theory. These results also indicate that the space charge effect on the ion beam focusing is negligible.

TABLE III

Location distance from electrode 34, mm.	Cross section	
	Measured from recording spot, mm.	Measured from electrostatic field plotting, mm.
.25	1	.75
.50	3	2
1.0	6	5

In order to switch or modulate an ion beam in air, consider an electric configuration in which a field is produced by a plurality of parallel wires or grids placed parallel to and spaced from an infinite plane electrode disposed adjacent to a number of similar conductor members, e.g., strips lying uniformly spaced and parallel to each other in the same plane. The equipotential surfaces near the region in which the grids are placed are critically controlled by the potentials on the strips. Assume a particular strip is charged at +300 volts, for instance. The lines of force initiated from this strip penetrate through the grid region to the potential surface of the plane electrode. The number of lines of force penetrating to the grid region depends upon the potential of the strip. For a similar strip charged to −30 volts, no lines of force can penetrate the grid region and link to the plane electrode. But consider that negative ions are coming from a −300 volt region and drifting under this field configuration. When the potential of the strip is +300 volts the ions can reach it. However, when the potential is −30 volts, they cannot. Thus the ion beam to the strip can be switched on or off by changing the strip potential from +300 volts to −30 volts and its intensity is modulated by the variation of the strip potential.

This modulation arrangement has been verified by the apparatus shown in FIG. 6. The structural arrangement of the corona discharge ion generator 10 is somewhat similar to that shown in FIGS. 1 and 3, with certain additions and modifications as follows: A 9 mm. diameter grid 38 having a 50 mil spacing between grid wires 38' is spaced 20 mils from a conductive diaphragm 40 provided with a circular aperture 42 therein. A 30 mil circular or cylindrical electrode 44 is arranged 20 mils from grid 38 effective as an ion current collector. The ion currents obtained at different potentials V_p are plotted in FIG. 7. By changing the potential from +300 volts to −30 volts the ion beam can be switched "on" and "off" and the linear relationship between the ion current and the potential on the collecting electrode 44 insures modulation of the beam intensity without distortion by applying a signal potential on the collecting electrode.

In order to print a sharp spot on a dielectric surface, the ion source must be placed very close to the dielectric surface. For this reason the ion source must be relatively small. A printing head structure can be constructed by utilizing the ion source and techniques heretofore described which eliminate most, if not all, of the previous disadvantages of printing head construction and operation.

Consider the structural arrangement of FIG. 8. The upper grid member 30 is secured to the base electrode 16 into which the bell jar 14 is suitably disposed, and is maintained at ground-earth potential. A second grid 46, disposed 3 mm. from grid 30, is secured to an electrically insulating member e.g., dielectric 48, attached to the base electrode 16 and is maintained at a positive potential, e.g., +100 volts. The electrode 16 is disposed approximately one centimeter from the cathode assembly 20. One or more pin-like electrodes 50, several mils in diameter, are disposed in parallel spaced apart relation insulated from each other, approximately 1 mm. from the lower grid 46. Dielectric recording material 52, e.g., Mylar tape, is disposed between the grid 46 and the pins 50 and separated from the Mylar material by approximately ½ mm. The Mylar material may be in tape form and caused to move over the electrodes in a known manner. It is noted that the size of the pin electrode 50, the spacing between pins and the voltages applied thereto determine the size of the recorded spot on the record medium. A signal voltage of only several hundred volts in magnitude is sufficient to accomplish printing. V_p represents the signal voltage applied to the pins 50. The values V_C and V_p can be adjusted to obtain the printing conditions desired, e.g., speed of operation of the device—the speed with which printing is accomplished.

It is seen most clearly in FIG. 10 that legible, dense, sharply defined intelligence bearing indicia can be produced by the means herewithin described.

As earlier described, positive ion beams readily can be obtained with this invention through the relatively simple expedient of changing the polarity of the electrical potentials applied to V_C and V_p. With reference to the structure shown in FIG. 8 for example, V_C would have a positive high potential applied thereto on the order of 9–10 kv. while V_p would have a negative potential applied at the same level as before. The potential on the grid 46 would be reversed in polarity from that shown.

It can be seen that electrostatic printing in colors could be attained by having different color inks attracted to the negative or positive regions.

It is apparent that the present ion source and ion beam switching technique can be utilized to construct an audio sound tape recording apparatus. A dielectric recording tape 52 can be made to move uniformly in front of an electrode 50. The desired audio signal, after amplification, is introduced to the electrode 50 as V_p and the amount of charge deposited on the dielectric tape is linear-

ly proportional to the sound input. This insures no harmonic generation or distortion through the recording process. The deposited charge may easily be reconverted to sound simply by the utilization of an electrostatic pick-up electrode.

The density of ink particles on a spot for printing intelligence, or the loudness of the sound for sound recording is linearly controlled by the voltage of the incoming signal.

It should be pointed out that the present controlled ion source has a high degree of efficiency in memory storage utilizing the techniques described hereinabove, a definite and prescribed amount of charge of either polarity can be placed on a dielectric member. An external signal can be employed to switch the ion beam on and off so as to control both its intensity as well as the sign of its charge, thereby providing a simple and effective storage memory apparatus.

Reference has been made hereinabove to grids, one or more of which are illustrated in the various figures of the drawings. In those instances wherein multiple grids have been employed they act in the nature of a decelerating electrode with respect to the ion beam. Thus they effectively improve the sensitivity of the hereindescribed transducer apparatus. The shielding member which is employed with the signal probe electrodes tends to shield the member from the corona discharge except at such times as there is a potential applied to the signal electrode. Without the shield there might be some current reaching the signal probe even though the latter member had no electrical potential or bias applied thereto.

What is claimed is:

1. Electrostatic transducer apparatus comprising:
(a) means producing a corona discharge,
(b) means operably associated with said discharge means for producing a shaped electrostatic field effective to focus ions produced by said corona discharge into a beam,
(c) means for decelerating said ion beam,
(d) means responsive to an applied potential for collecting said ions, and
(e) shield means operably associated with said collecting means and arranged in relative proximity thereto effective to control the ion beam and direct the beam to the collecting means preventing dispersal thereof.

2. Electrostatic transducer apparatus comprising:
(a) means producing a corona discharge for generating negative ions,
(b) means concentric with said discharge means for producing a shaped electrostatic field effective to focus ions produced by said corona discharge into a beam,
(c) means for decelerating said ion beam,
(d) means responsive to applied potentials for collecting said ions, and
(e) shield means operably associated with said collecting means and arranged in relative proximity thereto effective to control the ion beam and direct the beam to the collecting means preventing dispersal of said beam.

3. Electrostatic transducer apparatus comprising:
(a) means producing a corona discharge,
(b) means concentric with said discharge means for producing a shaped electrostatic field effective to focus ions produced by said corona discharge into a beam,
(c) a conductive grid for decelerating said ion beam,
(d) means responsive to applied potentials for collecting said ions,
(e) shield means closely juxtaposed with respect to said collecting means effective to control the ion beam and direct and concentrate the beam to said collecting means preventing dispersal of said beam, and
(f) means operably associated with said collecting means for receiving and storing electric charges thereon in response to the application of potential to said signal responsive means.

4. Electrostatic transducer apparatus comprising:
(a) corona discharge means for producing ions in atmospheric air,
(b) means operably associated with said corona discharge means for applying a shaped electrostatic field to said discharge effective to focus ions produced thereby into a beam,
(c) decelerating means disposed in the path of movement of said ion beam,
(d) signal responsive collecting means in the focus of said ion beam for attracting ions thereto as a result of an applied potential,
(e) means shielding said collecting means from said corona discharge disposed in close juxtaposition to said collecting means effective to control and concentrate said ion beam to said collecting means thereby preventing dispersal of said beam, and
(f) means intermediate said discharge means and said signal responsive means for receiving and storing electric charges thereon in response to the application of potential to said signal responsive means.

5. Electrostatic transducer apparatus comprising:
(a) corona discharge means for producing negative ions in atmospheric air,
(b) means operably associated with said corona discharge means for applying a shaped electrostatic field to said discharge effective to focus ions produced thereby into a beam,
(c) decelerating means disposed in the path of movement of said ion beam,
(d) signal responsive means in the focus of said ion beam for attracting ions thereto as a result of an applied potential,
(e) concentric shield means for shielding said collecting means from said corona discharge arranged within the field produced by the lines of force of said corona discharge means effective to concentrate said ion beam to said collecting means thereby preventing dispersal of said beam, and
(f) means intermediate said discharge means and said signal responsive means for receiving and storing electric charges thereon in response to the application of potential to said signal responsive means.

6. Electrostatic transducer apparatus comprising:
(a) corona discharge means for producing ions in atmospheric air,
(b) means operably associated with said corona discharge means for applying a shaped electrostatic field to said discharge effective to focus ions produced thereby into a beam,
(c) decelerating grid means disposed in the path of movement of said ion beam,
(d) signal responsive means in the focus of said ion beam for attracting ions thereto as a result of an applied potential,
(e) electrically conductive means shielding said collecting means from said corona discharge arranged within the field produced by the lines of force of the corona discharge field producing means effective to control and concentrate said ion beam to said collecting means thus to avoid scattering and dispersal of said beam, and
(f) means intermediate said discharge means and said signal responsive means for receiving and storing electric charges thereon in response to the application of potential to said signal responsive means.

7. Electrostatic transducer apparatus comprising:
(a) means producing a corona discharge for generating negative ions,
(b) means operably associated with said discharge means providing a shaped electrostatic field effective

to focus the ions produced by said corona discharge into a beam,

(c) signal responsive means located at the focus of said ion beam,

(d) one or more means intermediate said field shaping means for smoothing out the curvature of the equipotential surfaces adjacent said signal responsive means, and

(e) means arranged within the field produced by the lines of force of the corona discharge field producing means for causing said ion beam to collect at said signal responsive means when a signal potential is applied thereto.

8. Electrostatic transducer apparatus comprising:

(a) means producing a corona discharge,

(b) means operably associated with said discharge means providing a shaped electrostatic field effective to focus ions produced by said corona discharge into a beam,

(c) signal responsive means located at the focus of said ion beam,

(d) a pair of discontinuous means intermediate said field shaping means and said signal responsive means effective to smooth out the curvature of the equipotential surfaces adjacent said latter means, and

(e) means arranged within the field produced by the lines of force of said discharge producing means for causing said ion beam to collect at said signal responsive means when a signal potential is applied thereto.

9. Electrostatic transducer apparatus comprising:

(a) means producing a corona discharge,

(b) means operably associated with said discharge means for producing a shaped electrostatic field effective to focus ions produced by said corona discharge into a beam,

(c) means for decelerating said ion beam,

(d) one or more means responsive to an applied potential for collecting said ions, and

(e) means shielding said last means from said corona discharge arranged within the field produced by the lines of force of said discharge field producing means effective to control, concentrate and direct the ion beam to said collecting means.

10. Electrostatic transducer apparatus comprising:

(a) means producing a corona discharge for generating negative ions,

(b) means concentric with said discharge means for producing a shaped electrostic field effective to focus ions produced by said corona discharge into a beam,

(c) means for decelerating said ion beam,

(d) means responsive to applied potentials for collecting said ions,

(e) means shielding said last means from said corona discharge and arranged within the field produced by the lines of force of said discharge field producing means effective to control, concentrate and direct said ion beam to said collecting means, and

(f) means transporting a record medium across said ion collecting means effective to receive electric charges thereon representative of intelligence.

11. Electrostatic transducer apparatus comprising:

(a) corona discharge means for producing ions in atmospheric air,

(b) means operably associated with said corona discharge means for applying a shaped electrostatic field to said discharge effective to focus ions produced thereby into a beam,

(c) decelerating means disposed in the path of movement of said ion beam,

(d) signal responsive collecting means in the focus of said ion beam for attracting ions thereto as a result of an applied potential,

(e) means shielding said collecting means from said corona discharge arranged within the field produced by the lines of force of said discharge field producing means effective to control, concentrate and direct the ion beam to the collecting means,

(f) means intermediate said discharge means and said signal responsive means for receiving and storing electric charges thereon in response to the application of potential to said signal responsive means, and

(g) means for applying an audio frequency modulating potential to said signal responsive means effective to produce an audio recording on said storing means.

12. Electrostatic transducer apparatus comprising:

(a) corona discharge means for producing negative ions in atmospheric air,

(b) means operably associated with said corona discharge means for applying a shaped electrostatic field to said discharge effective to focus ions produced thereby into a beam,

(c) one or more decelerating means interposed in the path of movement of said ion beam,

(d) a plurality of signal responsive means forming a matrix located in the focus of said ion beam for attracting ions thereto as a result of an applied potential,

(e) concentric shield means for shielding said collecting means from said corona discharge arranged within the field produced by the lines of force of said discharge field producing means effective to control, concentrate and direct the ion beam to said collecting means,

(f) means intermediate said discharge means and said signal responsive means for receiving and storing electric charges thereon in response to the application of potential to said signal responsive means, and

(g) means transporting said last means across said matrix whereby a continuous recording is produced.

13. Electrostatic transducer apparatus comprising:

(a) corona discharge means for producing ions in atmospheric air;

(b) means operably associated with said corona discharge means for applying a shaped electrostatic field to said discharge effective to focus ions produced thereby into a beam,

(c) a first decelerating grid in the path of said ion beam,

(d) a second decelerating grid means disposed in the path of movement of said ion beam,

(e) one or more signal responsive means in the focus of said ion beam for attracting ions thereto as a result of an applied potential,

(f) electrically conductive means shielding said collecting means from said corona discharge arranged within the field produced by the lines of force of said discharge field producing means effective to control, concentrate and direct the ion beam to the collecting means, and

(g) means intermediate said discharge means and said signal responsive means for receiving and storing electric charges thereon in response to the application of potential to said signal responsive means.

14. Electrostatic transducer apparatus comprising:

(a) corona discharge means for producing negative or positive ions in atmospheric air,

(b) means operably associated with said discharge means for applying a shaped electrostatic field to said discharge effective to focus ions produced thereby into a beam,

(c) means adjustably mounting said discharge means for movement relative to said last named means,

(d) decelerating means disposed in the path of said beam,

(e) signal responsive ion collecting means in the focus of said ion beam for attracting ions thereto as a result of an applied potential,

(f) means shielding said collecting means from said corona discharge and arranged within the field produced by the lines of force of said discharge field

producing means effective to control, concentrate and direct said ion beam to said collecting means thus to avoid scattering and dispersal of said beam, and

(g) means intermediate said discharge means and said signal responsive means for receiving and storing electric charges and arranged within the field produced by the lines of force of said discharge field producing means effective to control, concentrate and direct said ion beam to said collecting means thus to avoid scattering and dispersal of said beam to said signal responsive means.

15. Electrostatic corona discharge apparatus comprising:

(a) a cathode assembly including one or more pin-like electrodes,

(b) an anode assembly including a central aperture therein,

(c) means mounting said cathode assembly adjacent said anode assembly in a manner permitting adjustment of the relative spacing therebetween,

(d) said anode and cathode assemblies including means for applying suitable potentials thereto effective to produce a corona discharge for generating negative or positive ions,

(e) a decelerating grid disposed adjacent said aperture,

(f) an electrode assembly concentric with said anode assembly for applying an electrostatic field to said discharge effective to focus ions produced thereby into a beam,

(g) means in the focus of said ion beam for collecting ions therefrom, and

(h) means shielding said collecting means from said discharge except when a potential is applied thereto.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,358,289 December 12, 1967

Po Lee

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 5, line 71, for "-300 volt" read -- -3,000 volt --; column 11, line 6, beginning with "electric charges" strike out all to and including "means." in line 10, same column 11, and insert instead -- thereon in response to the application of a signal potential to said signal responsive means. --; column 12, line 9, for "except when a potential is applied thereto." read -- and arranged within the field produced by the lines of force of said discharge field producing means effective to control, concentrate and direct said ion beam to said collecting means thus to avoid scattering and dispersal of said beam. --.

Signed and sealed this 11th day of February 1969.

(SEAL)

Attest:

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