

June 10, 1952

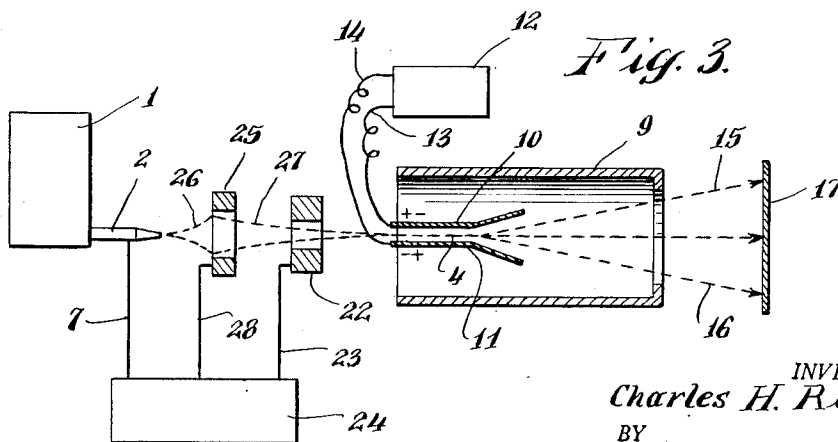
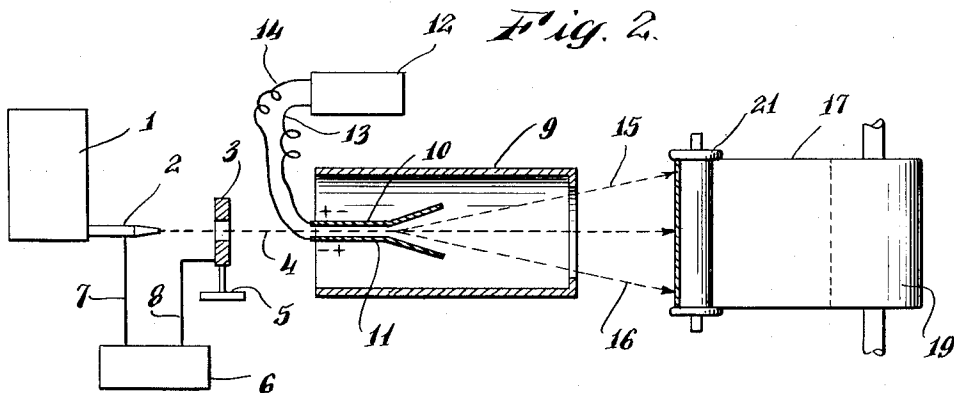
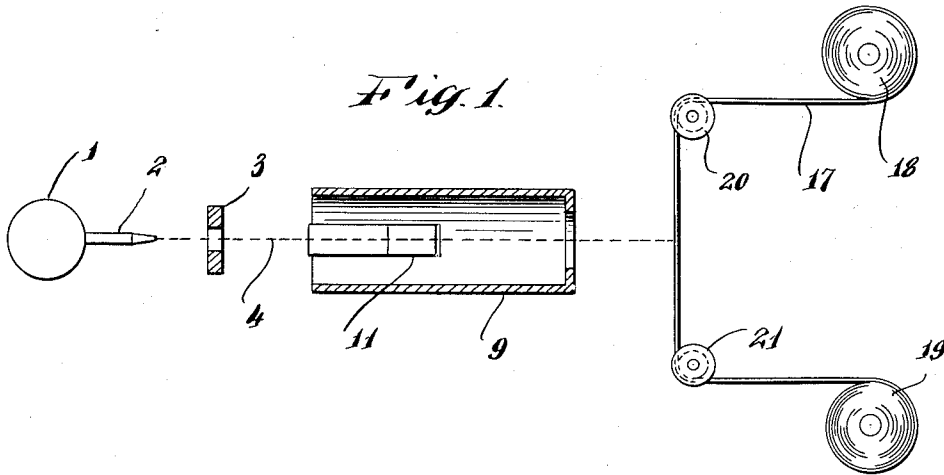
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2,600,129

APPARATUS FOR PRODUCING A STREAM OF ELECTRICALLY
CHARGED MULTIMOLECULAR PARTICLES

Filed July 17, 1948

2 SHEETS—SHEET 1



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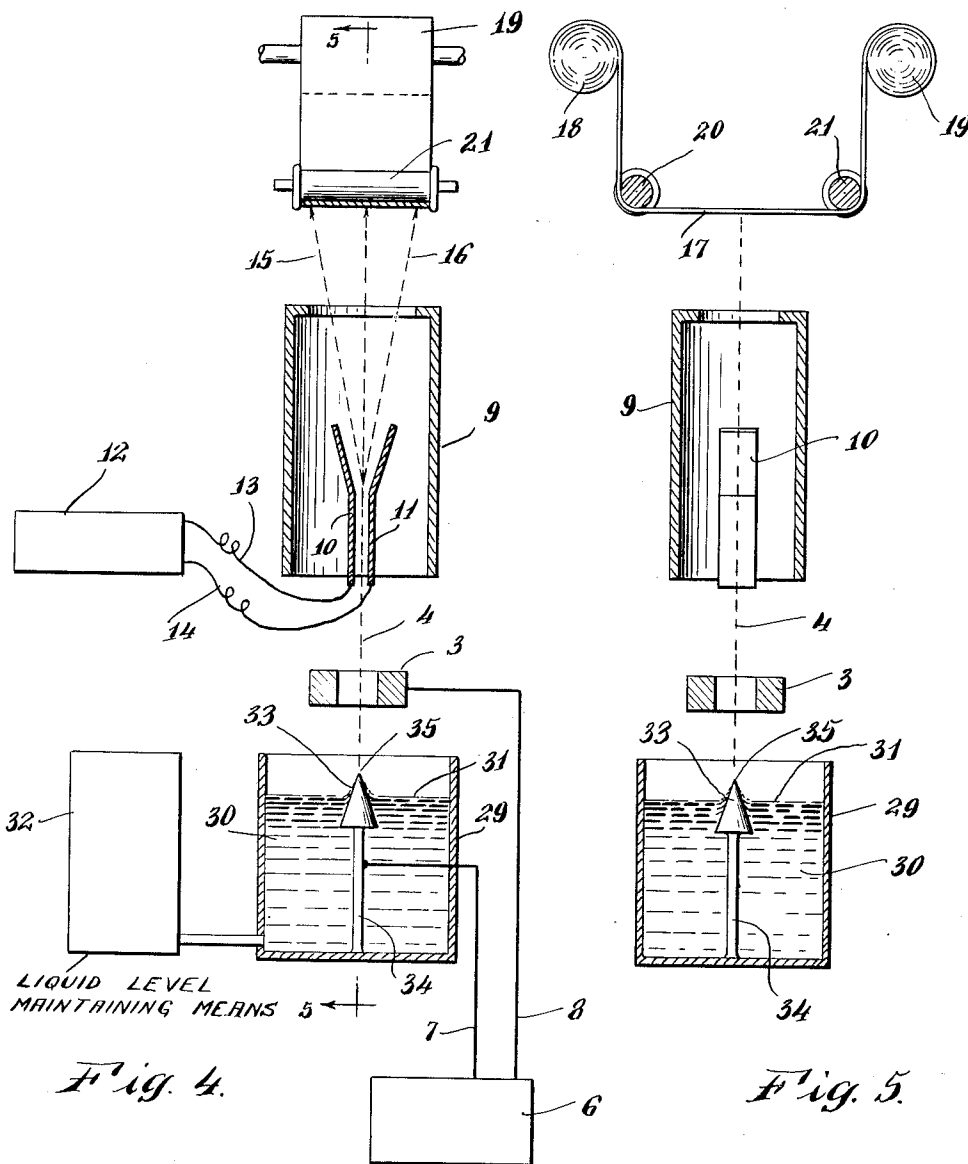
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2 SHEETS—SHEET 2



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UNITED STATES PATENT OFFICE

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APPARATUS FOR PRODUCING A STREAM OF
ELECTRICALLY CHARGED MULTIMOLECULAR PARTICLES

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Application July 17, 1948, Serial No. 39,364

7 Claims. (Cl. 299—1)

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My present invention relates to a method and a corresponding apparatus for use particularly in connection with recording or indicating devices, by which various phenomena which are or are capable of conversion into electrical impulses or values may be indicated and/or recorded as on a moving strip of paper or other suitable recording means. More particularly the invention relates to a method of and apparatus for producing a stream of electrically charged multi-molecular particles of matter and for causing such a stream to flow in a predetermined path, the stream being one which is capable of being electrically deflected by electrostatic means, so that the deflections of the stream will be proportional in frequency and amplitude to the variations of the controlling electrical influences to be indicated and/or recorded.

In some respects, the present invention is similar to the well known cathode ray tubes now commonly in use in many electrical fields, including television, wherein a stream of electrons is created by cathode emanation, and this stream is then deflected, usually in one direction by one set of electrical values and in another and perpendicular direction by another set of such values. In the present case it is desired that the stream be composed of multi-molecular particles as distinguished from sub-atomic electrons, and that it be caused to flow in an air-filled space, such as a room, without requiring it to be enclosed in an evacuated envelope of glass or other material, and without requiring many of the special precautions and apparatus used in conjunction with cathode ray tubes. In this way a fluid, such as ink for example, may be caused to flow as a very fine stream of electrically charged particles, which stream is capable of being deflected laterally in one plane only and in accordance with certain varying electrical values, then the stream be directed at a continuously and uniformly moving strip of paper or other material upon which a record may be made.

I am aware that such streams of ink or other similar materials have heretofore been produced, usually by hydrostatic pressure derived from the application to a reservoir of such fluid of a high gaseous pressure, causing the flow of the fluid through a very fine orifice of a nozzle; and further that such streams have been caused to flow by applying hydrostatic pressure to the liquid to force it through a nozzle by a high pressure pump in which the force is applied mechanically to the fluid to cause it to flow in the desired stream. Both these schemes have certain dis-

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advantages in that the stream is not accurately controllable in a desired manner for use in recording varying electrical values or impulses, at least not to the same extent as a stream caused to flow in accordance with the present invention or by the application of high potential electrostatic energy in an arrangement in which the stream would not flow, were it not for the application of this high potential electrostatic energy. In other words, in accordance with the present invention, it is possible to do away with the requirements for a high gaseous pressure applied to a body of fluid in a container, or for the requirements of a high pressure pumping apparatus of some kind, and cause the stream to flow solely by the application of high potential electrical energy. The provision of a method of causing a stream of the character described to flow by the use of such applied high potential electrical energy is a primary, general object of the present invention.

Among the more specific objects of the invention are to provide a method and an apparatus for causing the flow of a stream of multi-molecular charged particles of a liquid such as ink in the manner aforesaid, so that when the stream is deflected in accordance with variations of electrical values, or values which may be translated into electrical values, the ink may make a permanent record of the varying conditions to be indicated and/or recorded upon a moving body such as a strip of paper.

A further object of the present invention is to provide different embodiments of the method and apparatus as aforesaid, wherein the stream may be caused to flow by the use of one or more intermediate accelerating electrodes, assisting in concentrating the stream within the desired fine line or lines and wherein the velocity of the stream may be accurately controllable to effect desired results from the point of view of recording varying values of electrical magnitudes.

A further and more specific object of the present invention is to provide an embodiment thereof as aforesaid, wherein matter such as a liquid may be caused to flow through a nozzle under the influence solely of high potential electric energy applied between the nozzle, which is of electrically conducting material, and an annular electrode spaced from the nozzle and through which the stream is adapted and caused to flow, the nozzle being one which has an orifice so small that, considering the physical characteristics of the liquid, viz. surface tension, were it

not for the applied high potential energy, the liquid would not flow through the nozzle.

A further object of the invention is to provide another embodiment thereof, wherein a pointed element of electrically conducting material is provided associated with a supply body of matter for forming a stream as aforesaid, and wherein the stream of matter is caused to flow from the point of the pointed element in a predetermined path in alignment with and extending away from this point. More specifically, it is an object of the present invention to provide a supply body of liquid in a container wherein the liquid is maintained at a predetermined level and wherein the pointed element is disposed in the liquid with the point thereof extending slightly above the surface at the maintained level, so that the liquid may pass to the point of the element by capillary action and may then be drawn therefrom into a substantially vertical stream as aforesaid by the action of high potential electrical energy applied between the pointed element and an annular electrode aligned with the intended path of the stream and spaced from the pointed element.

Other and more detailed objects of the present invention will become apparent from the following description and appended claims, when considered in connection with the accompanying drawings in which:

Figure 1 is a view substantially in plan illustrating principally diagrammatically one embodiment of the invention, certain portions being shown in central horizontal section;

Fig. 2 is a view similar to that of Fig. 1, but showing the apparatus thereof principally in elevation, to illustrate the action of the deflecting plates or electrodes in deflecting the stream created or caused to flow in accordance with the present invention;

Fig. 3 is a view similar to that of Fig. 2, showing a slightly modified form of the invention;

Fig. 4 is a view of a still further embodiment of the invention in which a stream is caused to flow substantially vertically from a pointed element in part immersed in a liquid of which the stream is formed; and

Fig. 5 is a view taken substantially on the line 5—5 of Fig. 4.

While the invention is susceptible of many practical embodiments, a number of which I have actually built and operated in the development of this invention, it has its main utility in the creation of a stream of electrically charged particles which are multi-molecular in character, as distinguished from the sub-atomic or electronic particles in a cathode ray tube, and which (in the present case) may be caused to flow through ordinary atmosphere at normal room pressures and temperatures for use in conjunction with the recording of varying electrical values or values which may be translated suitably into electrical values. Again, while the stream could be of different types of matter, such as solids in fine particle form or gases, I have found it most convenient to apply the invention to producing a stream of fine electrically charged particles of an ordinary liquid such as ink, which may be used directly in making a record upon a sheet of paper. The embodiments of the invention hereinafter described are all in the preferred classes as just set forth.

Again, while the stream may be formed of liquid, which is electrically conducting and which might or might not be used as a conductor for a current of electricity, the present invention is

independent of the electrically conducting character of the liquid itself, so that it may be used, for example, with a solution of an electrolyte, which will be electrically conductive or with colloidal suspensions of solids, whether or not the particles are per se electrically conducting and including a conducting or non-conducting truly liquid phase; or it may be used in conjunction with non-conducting liquids, such as organic solvents, wherein a desired color may be imparted to the liquid by the use of dissolved dyes and the like. In any event, the particles of which the stream is formed in accordance with the present invention are multi-molecular in character, as distinguished from sub-molecular or sub-atomic particles, such as electrons which make up the stream flowing in a cathode ray tube, for example.

Once the stream is formed according to the present invention, the deflection thereof, as hereinafter described in connection with the embodiments of the invention shown in the drawings, may be effected in a manner similar to the deflection of an electron stream in a cathode ray tube and similar to the manner which would be used were the stream formed in accordance with the prior art practices by the use of applied hydrostatic pressure to a liquid to cause it to flow through a fine nozzle. Such deflection arrangements are shown, for example, in the patents to Hansell, No. 1,941,001 and Schröter, No. 1,882,043.

Turning now to the embodiment of the invention shown in Figs. 1 and 2, there is illustrated at 1 a container for a body of matter, which in the present embodiment is a liquid such as ink. Associated with the container 1 is a nozzle 2 of electrically conducting material and which has a very fine hole or aperture therethrough for the liquid to pass to form the desired stream. The diameter of this aperture is preferably in practice so small, in consideration of the physical characteristics, particularly the surface tension, of the liquid used, that were it not for applied high potential electrical energy, as hereinafter set forth, the liquid would not flow through the nozzle 2 under any pressure which is available within the container 1. In practice, in accordance with the present invention, the matter in the container 1 is only subjected to such hydrostatic pressure as is incident to the height of the liquid above the level of the nozzle, the surface of the liquid being open to the atmosphere or at least maintained at substantially atmospheric pressure and no mechanical pumps of any kind being necessary or in fact employed to cause a flow of the liquid through the nozzle 2.

At a point spaced a predetermined and desired distance from the nozzle 2 is located an electrode 3, which in practice is an annular ring of electrically conducting material suitably supported in place in alignment with the nozzle 2 as shown and in alignment with the predetermined path for the stream of liquid which is indicated as the dotted line 4. It will be understood that the electrode 3 may be suitably supported as by means generally indicated at 5 at a desired point in respect to the nozzle 2 and container 1 as shown.

In accordance with the present method, there is applied between the nozzle 2 and the electrode 3 a high potential D.-C. electrical charge. As used herein, the term "D.-C." as applied to the electrical charge or to the high potential electric energy supplied to and used in the device of this invention is intended to cover any unidirectional electric current including partly or completely

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rectified A.-C. current, wherein all the particles caused to flow as a stream have the same electrical polarity. In Fig. 2 there is shown diagrammatically at 6 a suitable source of high potential electrical energy, which preferably is of an adequate order of magnitude as hereinafter set forth. This source has two terminals to which conductors 7 and 8 are connected, these conductors leading respectively to the nozzle 2 and the electrode 3, so that there is a desired potential difference between the nozzle 2 and the electrode 3.

This potential, when using a single electrode as is shown at 3 in Fig. 2, for example, should be at least about 3,000 volts. It may and often is much more, however, depending upon several variables: first, the space between the nozzle 2 or equivalent member and the electrode 3; second, the type of liquid of which the stream is composed, the viscosity and surface tension of different liquids apparently being the controlling factors as far as is now known; and, third, the characteristics of the stream which is to be formed in a given case. For example, using carbon tetrachloride with a spacing of about one inch between the nozzle 2 and the electrode 3, a voltage of about 4,000 volts is necessary to produce a satisfactory stream. When the distance between the electrode 3 and the nozzle 2 is increased to about two inches, a potential difference of about 10,000 volts is necessary to produce a satisfactory stream under otherwise equivalent conditions. Aqueous liquids act similarly to non-aqueous liquids such as carbon tetrachloride, but usually require somewhat higher voltages in order to produce equivalent results. There is apparently no positive critical upper limit to the potential which may be used, values up to about 40,000 volts having been tried and operating successfully.

The direction of the current, i. e. which of the lead 7 or 8 is positive and which is negative, is immaterial in accordance with the present invention as the method is equally operable if the conductors 7 and 8 are reversed, the only difference being that the particles in the stream flowing along the path 4 will be oppositely charged if the leads 7 and 8 be reversed.

I have found that by using the method herein set forth and with apparatus substantially as shown diagrammatically in Figs. 1 and 2, it is possible to cause a stream of particles along the path 4, which stream is capable of being deflected by electrical means and which may be used to make a mark upon a recording surface such as the sheet of paper. The present invention pertains to that portion of the apparatus of Figs. 1 and 2 thus far described.

There is also shown in Figs. 1 and 2 a shield 9 within which are a pair of deflecting electrodes 10 and 11 which are connected to an apparatus, generally indicated at 12, by suitable electrical conductors 13 and 14 respectively. When the apparatus designated at 12 is caused to create or translate values into variable electrical charges, i. e. a potential drop in one direction or the other as between the electrodes 10 and 11, and of suitable values, the stream will be deflected from the center path shown at 4 in directions indicated diagrammatically by the dotted lines 15 and/or 16. If then a strip of a recording material such as is diagrammatically shown at 17 be passed from a supply roll as 18 to a take up roll as 19 around intermediate or guide rollers 20 and 21, then a permanent record may be made upon the sheet 17, assuming the liquid used is one which is

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capable of making such a record, such as ink. This record will give an indication and a permanent record also of the variations in the electrical charges applied to the deflecting electrodes 10 and 11.

Because of the manner in which the stream is created and the velocity of the particles created in this manner and in accordance with the method of the present invention, the response on the final record is almost instantaneous in recording even slight variations in the charges applied to the deflecting electrodes. Furthermore, by control of the potential between the nozzle 2 and the electrode 3, the stream can be caused to vary in velocity, so as to increase or decrease the sensitivity of the recording. If then the rate of movement of the paper record is maintained constant and at some known rate, the chart will give an accurate permanent record of the electrical impulses or charges to be recorded. This is particularly advantageous and desirable in recording the heart action of a patient by electro-cardiographic methods. Furthermore, at any desired time the flow of the stream can be stopped by interrupting the applied electrostatic potential between the electrode 3 and the nozzle 2, all without causing a substantial loss by spilling or otherwise wasting of the fluid being used and without allowing such leakage thereof as may be undesired in a sensitive apparatus.

Referring now to Fig. 3, there is illustrated an apparatus and a method similar in many respects to that above described in connection with Figs. 1 and 2, similar parts being given the same reference characters. In this case, however, there are at least two electrodes, one of which is shown at 22 and which is connected by a conductor 23 to a high potential D. C. electrical energy source generally indicated at 24. This source is similarly connected to the nozzle 2 by a conductor 7 as above described. The potential drop between the conductors 7 and 23 may be of the order of magnitude previously described, i. e. at least about 3,000 volts, but in most cases is substantially higher. In addition, however, there is shown in this form of the invention an additional accelerating electrode 25, which in addition to its accelerating function has a further function of assisting in confining the stream of matter being discharged or drawn from the nozzle 2 as indicated in dotted lines at 26 and 27, the stream coming from the nozzle 2 in the form of a substantially conical diverging spray and being restricted or converged and confined down toward a narrow stream as shown at 27, so that by the time the stream passes between the electrodes 10 and 11, it is in the form of a fine, narrow stream. In practice, the potential between the nozzle 2 and the electrode 25 is preferably substantially less than that between the nozzle and the electrode 22, for example, a value in the order of about 7,000 volts as between the nozzle 2 and the electrode 25 may be used where the potential difference between the nozzle and the electrode 22 is about 20,000 volts. For this purpose the electrode 25 is electrically connected to the source of high potential energy 24 by a conductor 28. The potential at the electrode 25 may be suitably adjusted to obtain the desired results, substantially as illustrated in the drawing.

While there is illustrated in Fig. 3 of the drawings an arrangement where in two successive electrodes are used in first creating a stream in the form of a divergent spray and thereafter focussing that stream, it is contemplated that

any desired number of electrodes may be used in accordance with the results to be obtained and the liquid being used in creating the stream. In general, it has been found that a substantially larger potential is required to form a spray, as shown in Fig. 3, than to form the same liquid into a stream as shown in Fig. 2. Further, when using a plurality of electrodes it is normally contemplated that the potential from the point of origin of the stream to the successive electrodes will be progressively greater along the path of travel of the stream although variations of this arrangement have been successfully employed.

Turning now to the form of the invention shown in Figs. 4 and 5, there is illustrated a container 29 for a body of the matter used which in the usual case will be a liquid, such as ink. This liquid is shown at 30 and is preferably maintained up to a predetermined desired level indicated at 31 by any suitable liquid level maintaining means 32 which is designated on the drawing by a suitable legend "Liquid Level Maintaining Means." As there are many known types of liquid level maintaining means, no particular description of any one such means will be included herein, it being understood that a suitable type will be chosen to maintain the level of the liquid 30 in the container 29 at a desired point as indicated at 31.

Arranged to be supported and substantially immersed in the liquid 30 is a pointed element 33 shown supported by a suitable stem 34 from the bottom of the container 29. It will be understood, however, that this element may be suitably supported in any desired manner in the container, preferably so that the point thereof, indicated at 35, will protrude slightly above the maintained level 31 of the liquid in the container. This position of the point 35 is preferably, however, such that the liquid may pass up to this point by capillary action, which will be a function of the particular type of liquid used. In a practical installation it may often be found convenient to have the pointed element 33 arranged for vertical adjustment in the container 29 as by threading it onto a post or other supporting means as 34 in an adjustable manner as will be obvious to those skilled in the art, but which is not particularly illustrated in the drawing.

The preferred path for the stream of charged particles in this embodiment of the invention is substantially vertically upward as shown, this path being indicated by reference numeral 4, as in the first embodiment of the invention hereinabove described. At a point spaced along this path from the point 35 of the element 33 is arranged an electrode 3 which has the same function as in the form of the invention shown in Figs. 1 and 2. There is also provided a suitable source of high potential direct current electric energy 6 which may be the same as the correspondingly numbered apparatus in Fig. 1. The source 6 is connected to the electrode 3 here by a conductor 8 and to the element 33 by a conductor 7 as shown. It will be understood that the stem 34 and the element 33 are both of electrically conducting material in the form shown, so that the element 33 will have an electrical potential in respect to the electrode 3 of a desired magnitude, for example, at least about 3,000 volts. The remaining elements shown in Figs. 4 and 5 have the same function and are numbered in the same way as the corresponding elements in the form shown in the Figs. 1 and 2.

It will be understood in respect to the form of

the invention shown in Figs. 4 and 5, that there will be no forces effective upon the liquid other than the high potential electrical energy applied as aforesaid, tending to cause a flow of the liquid along the path 4, and, therefore, there will be no flow except during such times as the electrical energy is applied from the source 6. Thus, if at any time it be desired to stop the flow of the stream of liquid, all that is necessary to do is to cut off the supply of electrical energy through the conductors 7 and 8 or one of them. There is thus provided an accurate controllable apparatus, which will not at any time tend to spill ink (if ink be used) around other parts of the apparatus where it is not desired to have it. At the same time the stream may be accurately controlled by controlling the applied potential; and the stream as formed in accordance with the present invention may be deflected as aforesaid and as taught in the prior art for the deflection of streams caused to flow by the hydrostatic pressure.

While there is herein shown and described but a few of the many possible embodiments of the invention, it will be understood that the principles herein set forth may be applied in many ways in addition to those particularly illustrated and described, and which occur to those skilled in the art based upon the foregoing description. I do not wish to be limited, therefore, except by the scope of the appended claims, which are to be construed validly, as broadly as the state of the prior art permits.

What is claimed is:

1. Apparatus for producing a fine stream of electrically charged multimolecular particles of matter and causing it to flow in a predetermined path, which stream is capable of being deflected by electrical means, comprising a container for a supply body of said matter, an electrically conducting element in contact with said matter in said container and from which element said matter may pass from said container, the arrangement being such that said matter will not pass from said element in the absence of an applied electro-static field, a source of high potential D. C. electric energy of at least about 3,000 volts and having two terminals, an annular electrode positioned at a predetermined distance along said path from said container and from said element and aligned and substantially concentric with said predetermined path of said stream, and electric conductors connecting said terminals respectively with said element and with said electrode, said electric energy being the sole applied force causing said matter to move from said container and serving to move said matter as a stream of multi-molecular particles, each particle having the same electrical polarity.

2. Apparatus in accordance with claim 1, wherein said matter is a liquid.

3. Apparatus in accordance with claim 1, wherein said matter is a liquid ink, the fine stream of which can be employed to make a visible record on a moving strip of paper.

4. Apparatus in accordance with claim 1, wherein said source of high potential D.-C. electric energy has three terminals, between the first and second of which is a potential of at least 3,000 volts and between the first and third of which is a potential substantially greater than 3,000 volts; and wherein an additional annular electrode is positioned substantially concentric with said predetermined path of said stream and at a distance from said element greater than the

distance between said element and the first named annular electrode, and a conductor from said third terminal of said source to said additional annular electrode.

5. Apparatus for producing a fine stream of electrically charged multimolecular particles of matter and causing it to flow in a predetermined path, which stream is capable of being deflected by electrical means, comprising a container for a supply body of said matter, a nozzle of electrically conducting material carried by said container and through which said matter may be caused to flow from said container, said nozzle having an orifice therethrough for the passage of said matter from said container which is so small in size in view of the physical characteristics of said matter, that said matter will not pass through said orifice due to the hydrostatic pressure of said matter in said container in the absence of an applied electro-static field, a source of high potential D.-C. electric energy of at least about 3,000 volts and having two terminals, an annular electrode positioned at a predetermined distance along said path from said nozzle and aligned and substantially concentric with said predetermined path of said stream, and electric conductors connecting said terminals respectively with said nozzle and with said electrode, said electric energy being the sole applied force causing said matter to move through and from said nozzle and serving to move said matter as a stream of multi-molecular particles, each particle having the same electrical polarity.

6. Apparatus for producing a fine stream of electrically charged multimolecular particles of matter and causing it to flow in a predetermined path, which stream is capable of being deflected by electrical means, comprising a container for a supply body of said matter, means for maintaining said matter up to a predetermined level in said container, which level is below said predetermined path, an electrically conductive pointed element arranged in said container and having its point above said predetermined level and directed along said predetermined path in the direction in which said stream is to be caused to flow, the arrangement being such that said matter will not pass from said pointed element in the absence of an applied electro-static field,

a source of high potential D.-C. electrical energy of at least about 3,000 volts and having two terminals, an annular electrode positioned at a predetermined distance along said path from said container and from said pointed element and aligned and substantially concentric with said predetermined path of said stream, and electric conductors connecting said terminals respectively with said pointed element and with said electrode, said electric energy being the sole applied force causing said matter to move from said container and from said element and serving to move said matter as a stream of multimolecular particles, each particle having the same electrical polarity.

7. Apparatus in accordance with claim 6, wherein said matter is a liquid capable of making a visible record on a sheet of paper, wherein said pointed element is arranged in said container with its point directed substantially vertically upwardly and projecting just above the surface of the liquid in the container, so that said liquid may reach substantially the point of said pointed element by capillary action and wherein said predetermined path for the stream of said liquid from said pointed element is substantially vertically upward from the point of said pointed element.

CHARLES H. RICHARDS.

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