

April 13, 1965

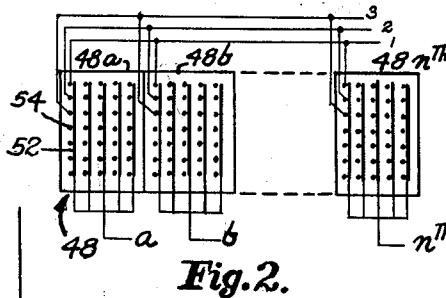
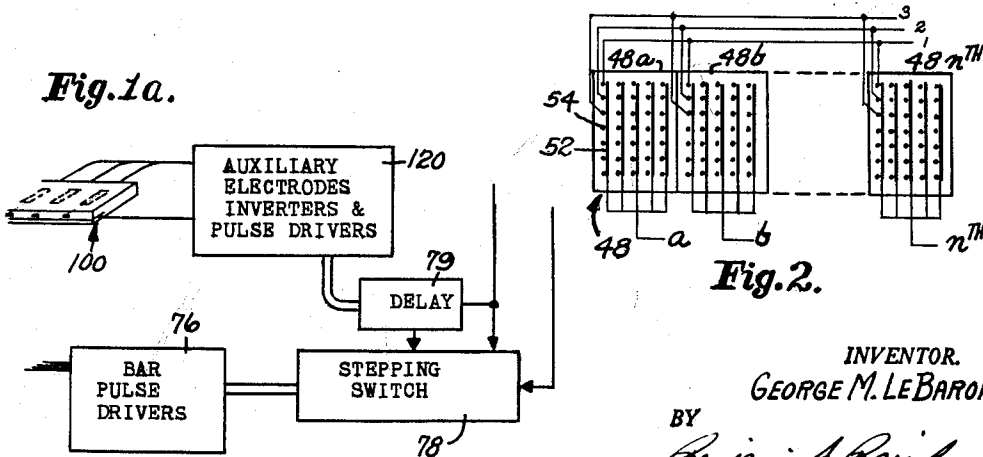
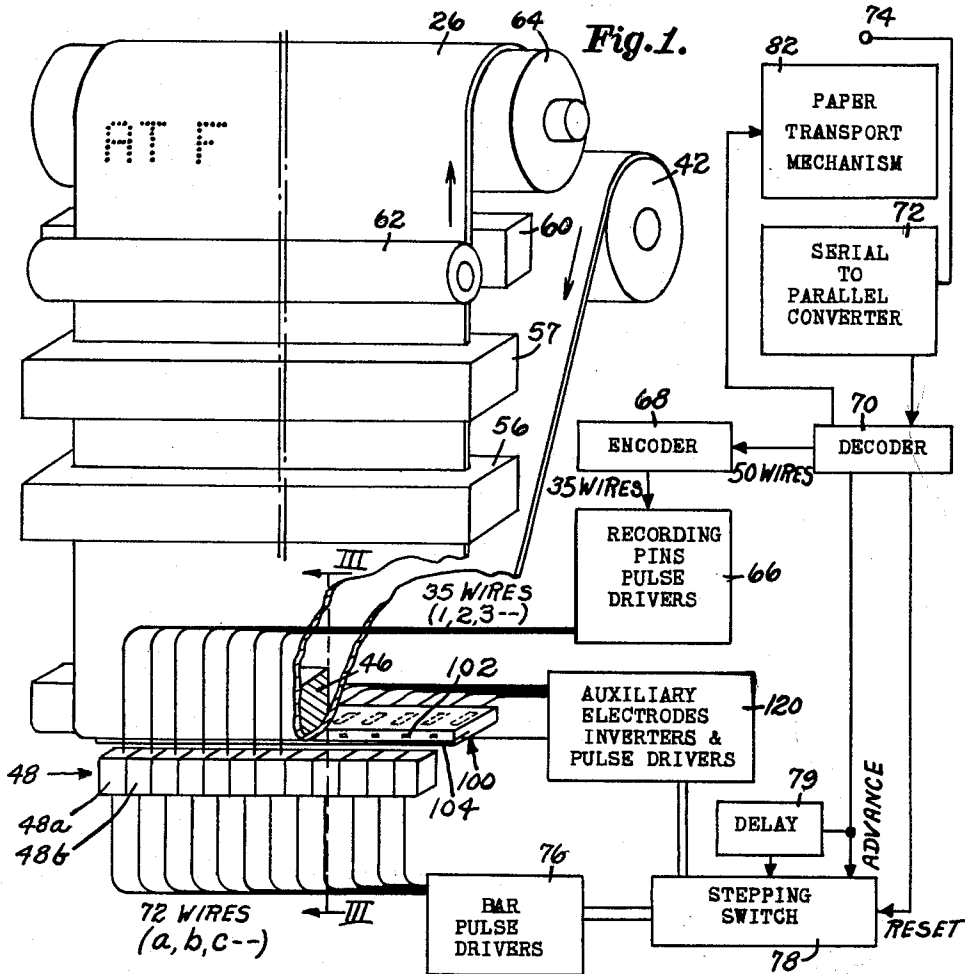
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3,178,718

ELECTROSTATIC RECORDING

Filed June 23, 1961

3 Sheets-Sheet 1



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Fig. 3.

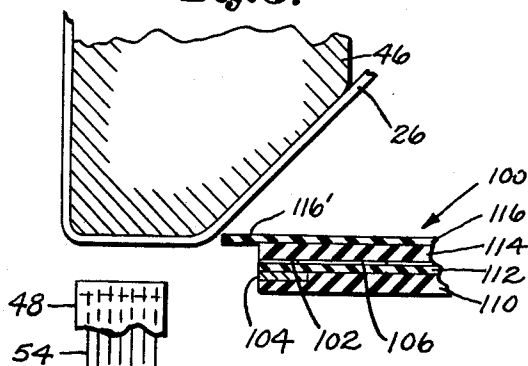


Fig. 4.

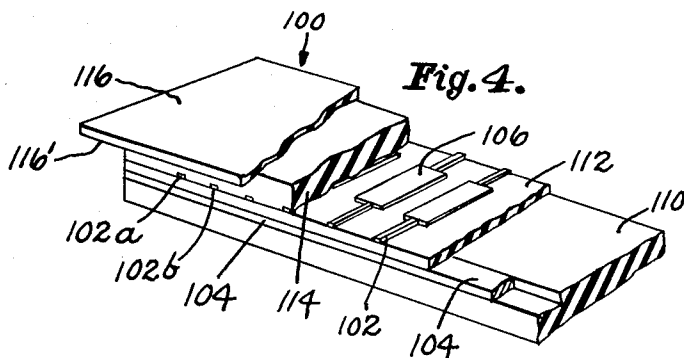
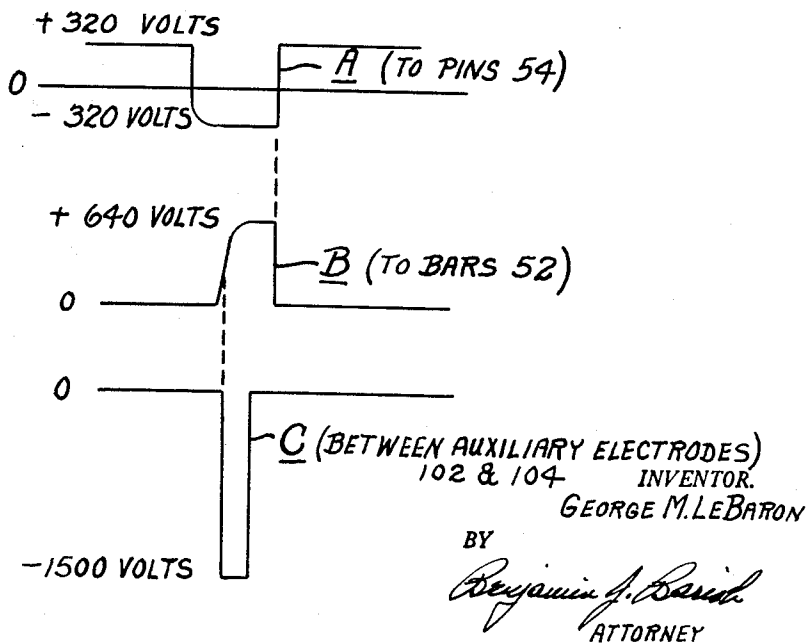


Fig. 5.



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Fig. 6.

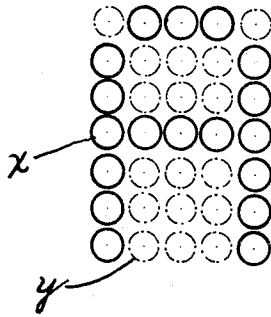


Fig. 7.

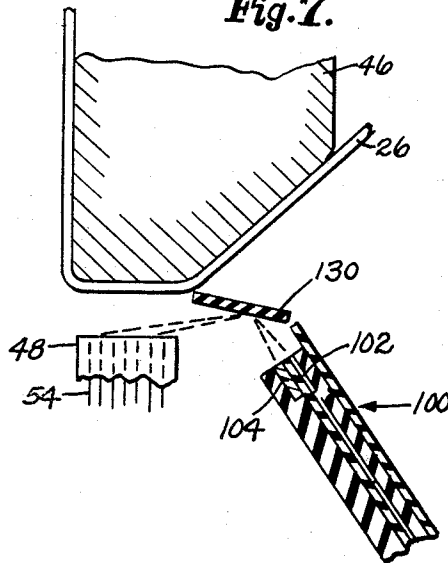
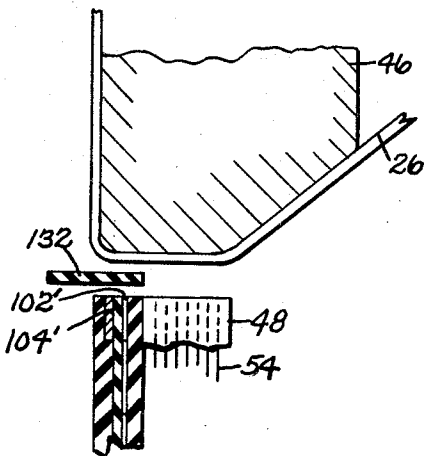


Fig. 8.



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3,178,718

ELECTROSTATIC RECORDING

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Filed June 23, 1961, Ser. No. 119,083

12 Claims. (Cl. 346—74)

The present invention relates generally to electrostatic recording and particularly to apparatus for electrostatic recording or printing alphanumeric information or other graphical data.

The electrostatic recording process is generally characterized by three broad steps. The first step relates to the establishment of electrically charged areas on selected portions of a recording medium, the charged areas being representative of the information to be recorded. In one common technique for recording alphanumeric information the charged areas are in the form of dots produced by a matrix of pin electrodes, the charged dot pattern being representative of the alphabetical or numerical characters being recorded. In another, the charged areas are produced by an electrode configured in accordance with the alphabetical or numerical character being recorded. The second step in electrostatic recording involves the developing of the charged areas on the recording medium. Ordinarily, in this step, the charged area is subjected to a powdered, dry ink which adheres to the charged areas, but not to the uncharged areas, thereby making the charged areas visible. In the third step, the powdered ink is fixed to the recording medium, as by a heat and/or pressure, to render the recorded information permanent on the medium.

The present invention is primarily directed to improving the first step, namely the establishment of the electrically charged areas on the recording medium.

Various techniques and apparatus have been devised for establishing the electrostatic charges on the recording medium, but they have generally suffered, in varying degrees, from a number of drawbacks. For one, the control of establishing the electrostatic charges was not always positive under different environmental conditions. That is, under one environmental condition, the equipment might operate quite reliably, but under another environmental condition, its operation would be much more erratic and unreliable. In many techniques, unreliable operation was particularly noticeable under low humidity conditions. Another drawback of the prior techniques was their dependency on very critical tolerances with respect to the spacing of the electrostatic recording electrodes. This was particularly true in the matrix type recording heads where the electrodes were in the form of a matrix of pins, predetermined ones of which were selected and subjected to voltage pulses to produce the electrostatic charged pattern on the recording medium. The required critical tolerances not only increased the cost of manufacture of such recording heads, but also rendered their operation unreliable and erratic when these critical tolerances were not met.

An object of the present invention is to provide improved electrostatic recording apparatus.

A particular object of the present invention is to provide electrostatic recording apparatus which is characterized by enabling more positive control in the formation and deposit of the electrostatic charges on the record medium.

Another object of the present invention is to provide electrostatic recording apparatus requiring less critical tolerances in the spacing and construction of the electrodes which enter into the electrostatic recording phenomenon.

A further object of the present invention is to provide

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electrostatic recording apparatus characterized by being more reliable in operation over a wide range of environmental conditions, particularly low humidity conditions.

Briefly stated, in constructing electrostatic recording apparatus in accordance with the invention, there is provided an auxiliary electrical discharge gap in the vicinity of the recording electrical discharge gap formed between the recording electrode and the charge-retentive medium upon which the electrostatic charges are established by the recording electrode. The auxiliary electrical discharge gap is comprised of a pair of electrodes which are separate and distinct from the recording electrode. It has been found that when an electrical discharge is effected in this auxiliary discharge gap at the time the voltage pulses are applied to the recording electrode, the electrical field discharge in the auxiliary gap influences that in the recording gap such that there is more certainty there will be an electrical discharge in the recording gap sufficient to establish the charge on the recording medium.

Since the electrodes forming the auxiliary discharge gap are separate and distinct from the electrodes of the recording gap, this system does not depend upon the critical relationship of voltage pulses and electrode spacings characteristic of many of the earlier systems. That is, much larger voltage pulses may be applied to the auxiliary electrodes without danger of interfering in an undesirable manner (such as causing discharges from unselected recording electrodes) with the electrodes in the recording gap. Therefore much more positive control of recording may be effected, and at the same time the critical tolerances of electrode spacing are obviated.

The auxiliary electrodes are positioned sufficiently close to the recording electrodes so that the electrical discharge produced in the gap of the former will have an influence in promoting an electrical discharge in the recording gap. This spacing is not required to be as close as the spacing between the recording electrodes themselves, for example in a pin-matrix recording head. In fact it is preferred to maintain a relatively large space between the auxiliary electrodes and the recording electrodes to permit more independent control, and it is one of the important advantages of this invention that this relatively large spacing is permitted. In practice, the spacing between the recording electrode and the electrodes forming the auxiliary gap are many degrees of magnitude larger than the spacing between the two electrodes forming the auxiliary gap. The auxiliary electrodes are oriented in the vicinity of the recording gap in shielded relation with respect to the record member so as not to produce an electrical discharge directly onto the record member.

For a better understanding of the invention, as well as other objects and features thereof, reference may be had to the detailed description of a preferred embodiment of the invention to follow. The invention is described as embodied in an electrostatic recording system generally similar to that illustrated in the patent application of Robert E. Benn, Richard S. Howell, and Richard S. Sakuri, Serial No. 734,253, filed May 9, 1958, now Patent No. 3,068,479, and assigned to the same assignee as the present invention. It will be appreciated that this embodiment of the invention is set forth merely for illustrative purposes, and that the invention itself is not limited to this embodiment.

Referring to the drawings:

FIG. 1 illustrates in block diagram form a page printer generally similar to that described in the above-identified application Serial No. 734,253 embodying the present invention;

FIG. 1a illustrates a portion of the system of FIG. 1, but showing a variation thereof in connection with the present invention;

FIG. 2 is a front plane view of the electrostatic print-

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ing heads of the system of FIG. 1 illustrating the electrode arrangement at the face thereof for establishing the electrostatic charges on the recording medium;

FIG. 3 is an enlarged fragmentary view, partly in section, along the lines III—III, FIG. 1;

FIG. 4 is a perspective view, partly in section, of the auxiliary electrodes utilized in the present invention;

FIG. 5 is a waveform diagram of several voltage pulses applied to different electrodes in the system of FIG. 1;

FIG. 6 is an enlarged representation of the pattern of electrostatic charges established on the record medium by effecting electrical discharges from the pin electrodes representative of the letter "A";

FIG. 7 is a view similar to FIG. 3 but illustrating a variation of the auxiliary electrodes; and

FIG. 8 is a further view similar to FIG. 3 illustrating another variation of the auxiliary electrodes.

Many of the elements that are common to those disclosed in the above-identified application Serial No. 734,253 carry the same reference numerals as in that application in order to facilitate an understanding of the present description.

With respect to FIG. 1, it is seen that this system includes a charge-retentive record medium 26 fed by means of supply roll 42 and take-up roll 64 past a line of electrostatic recording or printing heads 48. Each of the heads 48 is able to establish an electrostatic charge on the record medium 26 in accordance with the alphabetical, numerical, or other graphical information to be recorded or printed.

FIG. 2 illustrates the electrode face of each of the printing heads for establishing the charges on the record medium. Each of the heads is comprised of a matrix of equally-spaced, mutually insulated pins 54 arranged in a rectangular array of 5 pins in each vertical column and 7 pins in each horizontal row. The heads 48 are spaced from a back electrode or anvil 46 (FIGS. 1 and 3), the space between electrode 46 and each head 48 forming a recording electrical discharge gap through which the recording medium 26 passes. By effecting an electrical discharge between selected pins 54 and the recording medium, electrostatic charges are established on the latter in accordance with the selected pins, and therefore an electrostatic image representative of the selected pins is formed on the recording medium. FIG. 6 illustrates, in solid lines *x*, the pattern of electrostatic charges produced by effecting electrical discharges from the pin electrodes representative of the letter "A." The dotted lines 4 illustrate the areas of the remaining pin electrodes of the matrix from which electrical charges are not established.

The electrostatic recording system described in the above-identified application Serial No. 734,253 utilizes a plurality of bar electrodes 52 in each printing head 48 for effecting the electrostatic discharge from the selected pins 54. There are 5 bar electrodes 52 in each head 48, each of the bar electrodes cooperating with and being closely spaced to, but insulated from, a column of pin electrodes 54.

The system includes one head 48 for each character position in a printing line. In a preferred embodiment of the invention, 72 heads are provided, there being 72 characters to a printing line. FIG. 2 illustrates merely 3 of the heads, the first two being 48*a* and 48*b*, and the last one being designated 48(*n*th).

The electrical connections are such that all homologously situated pins 54 in all the heads 48 are connected together. Thus, it is seen in FIG. 2 that a common lead 1 is connected to the first pin 54 in the first head 48*a*, to the first pin 54 in the second head 48*b*, and so on to the last head 48(*n*th). A second common lead 2 is connected to the second pin 54 in the first head 48*a*, to the second pin in the second head 48*b*, and so on until the last head 48(*n*th). There being 35 pins in each head, there

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would be 35 of such common leads, each one connected to the corresponding 35 pins in all the heads.

All the bar electrodes 52 in an individual head are connected together to a common lead. For example, in FIG. 2, it is seen that all 5 bar electrodes in head 48*a* are connected to lead *a*, all 5 bar electrodes in head 48*b* are connected to lead *b*, and so on through the last head 48(*n*th) and lead (*n*th). There being 72 heads 48, there would be 72 of such output leads *a* . . . *n*th.

In operation, the character signals representative of the information to be recorded are first encoded in suitable form for energizing the pin electrodes 54 according to the spatial pattern representative of the character to be recorded, and are then distributed to homologously situated pins through leads 1, 2, 3, etc. With each distribution of said encoded signals, a further signal is applied in consecutive sequence to leads *a*, *b*, etc., to the bar electrodes 52 of their respective heads, the arrangement being such that the excitation of the bar electrodes of a particular head in coincidence with the excitation of the pin electrodes of the same head is effective to cause an electrical discharge from the selected pin electrodes of the head having the pulsed bar electrodes to the record medium 26. Since the character signals are always distributed to the selected pin electrodes of all the heads and the further signals are distributed to the bar electrodes of individual heads in consecutive sequence, it will thus be seen that the electrostatic recording from the heads will be serial from each head in consecutive order.

At this point it might be well to mention that some of the terminology used in the above-identified application Serial No. 734,253 (now Patent No. 3,068,479) is not used in the present description. For example, the pin electrodes 54 in that application are sometimes described there as being initiating electrodes, but they will be referred to in the present description as pin electrodes in accordance with their structure, or recording electrodes since the electrostatic charges established on the recording medium correspond to the shape of their electrode faces. Also, electrodes 52 in the above-identified application are sometimes referred to as print electrodes, but they will be referred to in the present description as bar electrodes, in accordance with their structure rather than their function. It is felt preferable to refer to, and to identify, these elements by their structural characteristics, rather than by their functional characteristics, since their functions and their modes of operation in the electrostatic recording phenomenon are not known with certainty. This is clear from the above-identified application where it was brought out that the exact mechanism of operation of the disclosed system of electrodes was not known, but the explanation given was deemed the one best known to the inventors at the time the application was filed.

Returning to FIG. 1, it is seen that the record medium 26 is fed from the supply reel 42 past the line of recording heads 48 which establish the electrostatic charges thereon, and from there through an inking station 56 where it is subjected to a dry, powdered ink. The ink adheres to the charged areas and therefore renders the charged areas visible. A small amount of ink may lightly adhere to the uncharged areas of the recording medium 26, but this ink is easily removed by slight agitation and/or by a vacuum cleaner illustrated schematically at 57. From the vacuum cleaner, the record medium passes between a heater, illustrated schematically at 60, and a pressure roll 62 for fixing the ink. The recording medium 26 in this embodiment is a plastic (e.g. polyethylene) coated paper having charge-retentive characteristics, and when it passes between the heater 60 and pressure roll 62, the plastic is softened and the ink is pressed into it to render it permanently bonded to the paper. From the fixing station, the paper is wound on take-up reel 64.

The control circuit for the electrostatic recorder is generally similar to that illustrated in the above-identified application Serial No. 734,253, and is depicted in FIG. 1

in block diagram form. The input to the recorder is in the form of serial signals and is applied to input terminal 74 which is connected to serial-to-parallel-converter 72. The latter converts the serial input signals to parallel signals and applies them to a decoder 70 which is in the form of a matrix having 56 output wires, 50 of which represent the characters (alphabet, numbers and selected symbols) to be printed, and the other 6 of which are used for control functions such as paper advance, space, carriage return, etc.

Depending upon the character signal applied to decoder 70, one of the 50 wires is energized to represent that character. The 50 character wires are connected to encoder 68 which encodes the signals in suitable form for application to the pin electrodes 54 of the heads 48, these electrodes being energized through pin pulse drivers 66. The latter drivers have 35 output wires, these being the wires 1, 2, 3, etc. (FIG. 2) which are connected to homologically situated pins 54 in all the heads 48 as de-

Besides generating the character signals applied to the pins 54 of the heads, decoder 70 also generates the signals applied to the bar electrodes 52. The latter signals are applied through a delay circuit 79, which interposes a predetermined delay (e.g. 50 to 100 milliseconds) with respect to the character signals applied to the pins. The delay signal from decoder 70 is then applied to a stepping switch 78 which distributes the signals consecutively to the bar pulse drivers 76 and thence to the bar electrodes 52 of the recording heads 48. For high speed operation, stepping switch 78 is preferably an electronic distributor. The same output signal from decoder 70 applied to the delay circuit 79 is also applied to advance the stepping switch 78 one position.

Thus it is seen that, for each character applied to the input, signals are distributed to the homologically situated pins 54 in all the heads, and that with each such distribution, a pulse is applied to the bars 52 in each head consecutively, thereby producing serial recording of the characters applied to the input circuit. When a line of printing is completed in this manner, a pulse is applied from decoder 70 to stepping switch 78 to reset the latter. At the same time, a signal is applied from decoder 70 to paper transport mechanism 82 to advance the record medium 26 to a new printing line.

The above system, in so far as described, was found to operate very satisfactorily under most environmental conditions. However, when the humidity dropped to a very low level it, was found that the heads frequently would not produce electrical discharges upon proper coincidence of pulses to the pin and bar electrodes, as they should have. In other words, this system was found to be somewhat humidity sensitive. This could not be cured by "brute-forcing" an electrical discharge, i.e., by applying larger voltage pulses to the electrodes, since the electrode spacing is very close and therefore there is somewhat of a critical relationship between the spacings of the electrodes and the voltage pulses that could be applied without producing electrical discharges from unselected pins or from unselected heads. In a commercial form of this system, the record face of each head 48 is dimensionally comparable to the printing face of a standard character printing element in a conventional typewriter, with each pin 54 being spaced about .002 inch (2 mils) from its respective bar electrode 52 and about .014 inch (14 mils) from its next nearest pin electrode.

The present invention has rendered such apparatus remarkably more reliable particularly under low humidity conditions, and has generally provided more positive control of the electrostatic recording under any operating condition. According to the present invention, the system includes an auxiliary electrical discharge gap in the vicinity of each of the recording electrical discharge gaps, that is, the space between each of the recording heads 48 and the charge-retentive medium 26. The electrodes forming this auxiliary gap are separate and distinct from those

in the recording gap and are sufficiently close to those in the recording gap so as to influence the electrical discharge therein, but not so close as to produce significant electrical discharge directly between the auxiliary and recording electrodes such as would cause discharges from unselected pins. Further, the auxiliary electrodes are oriented in shielded relation with respect to the record member so as not to produce electrical discharges directly onto the record member.

With reference to FIGS. 1 and 3, the auxiliary electrode system is illustrated as embodied in a stick 100 supported in the vicinity of the gap between the line of recording electrodes 48 and the back anvil 46 between which the record medium 26 passes. The stick 100 incorporates a plurality of pairs of auxiliary electrodes forming a plurality of auxiliary electrical discharge gaps, one gap for, and in alignment with, each gap formed by the individual heads 48. Each of the auxiliary gaps is comprised of a pin electrode 102 and a common elongated electrode 104. Since there are 72 heads 48 in the system described, there would be 72 auxiliary pin electrodes 102 in stick 100, but there is only one elongated electrode 104 extending longitudinally through the stick, this electrode being common to and cooperating with all of the pin electrodes 102. Each pin electrode 102 includes a resistor 106 (FIG. 4) in series therewith. All the pin electrodes 102 and the common electrode 104 are formed so as to terminate flush with the face of the stick 100 which is positioned in the vicinity of the recording electrical discharge gaps.

The construction of the stick 100 is shown particularly in FIG. 4. It may be produced by a laminating technique similar to that described in the patent application of Howell et al. Serial No. 856,868 for making the recording heads 48. In the construction illustrated in FIG. 4, common electrode 104 is formed on one face of a plastic lamina 110, such as an epoxy resin impregnated glass cloth, and is then covered by a thin layer of mica 112. The auxiliary pin electrodes 102 are formed on a face of another plastic lamina 114, which is also an epoxy resin impregnated glass cloth, the pins being produced as a result of etching away a metal cladding bonded to lamina 114 to leave, for each pin, two aligned metal portions spaced from each other. The resistor 106 (of about 100 kilohms) is deposited, as by a stencil, to bridge the two spaced portions of each pin, thus resulting in a resistor 106 being in series with each pin. Plastic lamina 114 carrying pins 102 and their respective resistors 106 is then placed over lamina 110 with the pins and resistors in contact with the mica layer 112. A film 116 of plastic material, preferably polyethylene terephthalate (obtainable under the trademark "Mylar"), is placed over the upper surface of lamina 114, and all the laminae are then bonded together under heat and pressure to form a unitary stick assembly.

As illustrated particularly in FIG. 3, Mylar film 116 is formed with an end 116' projecting over the face of the stick 100 which carries the exposed faces of auxiliary electrodes 102 and 104. Electrodes 102 and 104 produce an electrical discharge to influence the electrical discharge from the recording heads 48, and the purpose of the projection 116' of Mylar film 116 is to shield the record medium from the electrical discharge of these auxiliary electrodes so that the electric charges established on the record medium 26 will be only those produced by the recording pins 54 of heads 48. Electrodes 102 and 104 may be made of the same material as electrodes 54 and 52 of the recording heads, preferably stainless steel.

In the system of FIG. 1, the voltage pulses applied to auxiliary pin electrodes 102 and the auxiliary common electrode 104 are supplied from the stepping switch 78 which supplies the pulses to the bar electrodes 52 in the recording heads 48. For this purpose, each of the pin electrodes 102 is connected to the stepping switch through an inverter and a pulse driver, illustrated in block form in FIG. 1 and designated as 120. Thus, with each volt-

age pulse applied to a bar electrode 52, a pulse is also applied between auxiliary pin electrode 102 and auxiliary common electrode 104. Since the bar electrodes 52 are pulsed consecutively with each distribution of the character signals to the pins 54 of the heads, so an auxiliary electrode will be pulsed consecutively with each distribution of the character signals to the pin electrodes 54. In the system of FIG. 1, however, the voltage pulses applied to the auxiliary electrodes are of larger amplitude, and of inverted phase, when compared to those applied to the bar electrodes 52.

FIG. 5 illustrates these voltage pulses. Waveform A represents the voltage pulse applied to the pin electrode 54, and it is seen that the pin is normally maintained at +320 volts with respect to the reference potential, the latter being the potential applied to anvil 46 which is preferably 0 volts. A character signal applied to the pin 54 brings the voltage down to -320 volts, providing a total excursion of 640 volts. Waveform B illustrates the signal applied to bar electrodes 52 in the recording heads 48. These electrodes are normally maintained at the 0 reference potential, and rise to +640 volts with each pulse applied to these bar electrodes. It will be noted from the waveforms A and B that the voltage pulse applied to bar electrodes 52 coincide with the voltage pulses applied to the pin electrodes 54, except for the delay interposed by delay circuit 79. The auxiliary pin electrodes 102 are also pulsed in coincidence with the bar electrodes 52, but are driven from the 0 reference potential to -1500 volts.

In operation, voltage pulses derived from the character signals are applied to the selected pin electrodes 54 of the print heads driving them from their quiescent state of +320 volts to -320 volts. Since like pin electrodes of all the heads receive these pulses the negative value of the pulse is limited by the maximum voltage that can be applied to any pin electrode without causing an electrical discharge to occur in an improper head. The +640 volt pulse (curve B, FIG. 5) is applied to the bar electrodes 52 of the selected head and, being in coincidence with the pulse to the pin electrodes, promote the electrical discharge from the pin electrodes in that selected head. The maximum potential that can be applied to the bar electrodes is limited by that which will effect an electrical discharge from the pins of the selected head, and not from the pins of the unselected heads. In those pins which are to produce an electrical discharge, there will be a voltage difference of 960 volts from pin 54 to bar 52. This is usually sufficient to cause an electrical discharge from the pins and to deposit a charge on the record medium 26, but as indicated above, this does not always occur, particularly under low humidity conditions.

The maximum voltage difference between the auxiliary electrodes 102 and 104, however, is not limited as in the case of electrodes 54 and 52, since electrodes 102 and 104 are spaced from electrodes 54 and 52 many orders of magnitude when compared to the spacing between the auxiliary electrodes 102 and 104 themselves. Thus, a substantially larger voltage may be applied between these auxiliary electrodes such as will produce with more certainty an electrical discharge with every voltage pulse. In a preferred embodiment, auxiliary pin electrode 102 is spaced about .001 inch (1 mil) from the auxiliary common electrode 104, this being the thickness of mica layer 112. In contrast to this close spacing, the auxiliary electrodes 102 and 104, are together spaced from about .250 inch (250 mils) to about .500 inch (500 mils) from the closest pin electrode 54 of its respective head 48.

Instead of pulsing each of the auxiliary electrodes 102 and 104 individually in succession, i.e. with the bar electrodes 52 of the recording heads 48, it may be desirable to pulse all the auxiliary electrodes 102 and 104 of the complete stick 100 with every distribution of the character signals to the recording pin electrodes 54. This modification is illustrated in FIG. 1a, wherein it is seen that

the pulse drivers for the auxiliary electrodes 102 and 104 are connected directly to the delay circuit 79, and thereby bypass the stepping switch 78. An advantage in this modification is simplification of the system, in that the stepping switch need not be sufficiently large to handle the relatively large amplitude pulses applied to the auxiliary electrodes. On the other hand, this modification provides somewhat greater power drain, since all the auxiliary electrodes are pulsed with the recording of every character. Also there is a possibility of generating unfavorable electrostatic charges on the record medium 26, but in practice this tendency has been found to be minimal when projection 116' of the stick is properly disposed in shielding relationship to the record member. Further, the modification of FIG. 1a is not susceptible, as the system illustrated in FIG. 1, of utilizing the auxiliary electrodes 102 and 104, when consecutively pulsed, to effect an electrical discharge from preselected pins of preselected heads by coincidence pulse techniques, and thereby dispensing with the bar electrodes 52.

The exact mechanism by which the electrical discharge produced by the auxiliary electrodes 102 and 104 influences the electrical discharge produced by the pin electrodes 54, so that there is more certainty in the establishment of electrostatic charges on the record medium from the latter electrodes, is not known with certainty, but the following appears to be a plausible explanation. The initiation of an electrical discharge is usually considered to occur when an electron appears in a position where it can be accelerated to ionizing energy by the existing electric field. This electron can originate from any one of a number of processes, including (1) thermionic emission, (2) photoemission, (3) field emission from the cathode, or (4) other less probable but possible processes in the gas and at the cathode such as electron detachment from a negative ion, photoionization of the gas, ionization due to "background" radiation, etc. Unless other processes are specifically utilized, it is considered that field emission is the most probable cause of the appearance of the initiating electron in small gaps between two electrodes. The initiating electron is then accelerated by the electric field and collides with a gas molecule, this collision ionizing the molecule, producing a positive ion and another electron. The process repeats in cumulative fashion throughout the distance to the anode, thus producing a Townsend avalanche of electrons. According to this theory, the rate of production of ion pairs is proportional to the number of electrons at any one time.

It is thus seen that before there is sufficient breakdown of the electrostatic field produced by the pin electrodes 54 to deposit charges on the record medium 26, it is required that one or more initial electrons first appear in a favorable position in the gap to lead to the necessary avalanches, and then it is required that these avalanches develop and build up to a value sufficient to deposit the charges on the record medium. The time for the first to occur, that is for the appearance of the initial electrons, is normally referred to as the statistical time lag, whereas the time for the latter to occur is normally referred to as the formative time lag. It is known that where the gap is irradiated, the statistical time lag may be substantially reduced.

Consistent with the foregoing, it is believed that the auxiliary electrodes 102 and 104 produce an electrical discharge which irradiates the gap formed between the pin electrodes 54 and the record medium 26 and ionizes the gas in that gap to produce the initiating electron from which the electron avalanche is formed (process (4) above); and/or that the electrical discharge produced by the auxiliary electrodes 102 and 104 irradiates the pin electrodes 54, the latter ejecting the initiating electrons into the gap by photoemission (process (2) above). Either or both of these phenomena may explain how the auxiliary electrodes 102 and 104 influence the electrical discharge from pin electrodes 54.

Whatever the explanation, and it is understood that no particular explanation is relied upon, empirical results have demonstrated that the presence of the auxiliary electrodes 102 and 104 have a decided influence in assuring the deposit of electrostatic charges on the record medium 26 when character signals are applied to the pin electrodes 54 in coincidence with the application of pulses to the auxiliary electrodes 102 and 104. The effectiveness of the auxiliary electrodes was tested in the system of FIG. 1 at three environmental conditions—low, medium and high humidity. At medium and high humidity conditions, the system not including the auxiliary electrodes 102 and 104 produced equally good printing results as when the auxiliary electrodes were included. However, at low humidity conditions, at about 6% relative humidity and 82° F., the system utilizing the auxiliary electrodes produced outstandingly better results, as shown in the following table of the number of various characters not recognizable out of 100 lines of printing (1) when the system of FIG. 1 did not utilize the auxiliary electrodes 102 and 104, and (2) when the system did utilize the auxiliary electrodes:

Character	Without Auxiliary Electrodes 102 and 104	With Auxiliary Electrodes 102 and 104
A.....	255	None.
E.....	125	None.
<.....	670	None.
I.....	814	None.

It is not necessary that the auxiliary electrodes be directly in line with the pin electrodes 54 or the gap produced between the pin electrodes and the recording medium 26, in the manner illustrated in FIG. 3. The "radiations" (which is how they are termed here consistent with the foregoing possible explanations of their mechanism of action) may be reflected into the recording gap of pin electrodes 54. This is illustrated in FIG. 7, where it is seen that the stick 109 carrying the auxiliary electrodes 102 and 104 is positioned to one side and out of alignment with the pin electrodes 54, which may be required or found desirable for mechanical design and space considerations. The "radiations" produced by the auxiliary electrodes 102 and 104 are reflected into the recording gap by a dielectric sheet 130, such as mica.

It may be found desirable, for ease in manufacturing, to incorporate the auxiliary electrodes 102 and 104 within the recording head 43 itself which carries the pin electrodes 54. This is illustrated in FIG. 8 where it is also seen that a dielectric 132 is provided to reflect into the recording gap the "radiations" produced by the auxiliary electrodes 102' and 104', and also to shield the record medium 26 from these "radiations," to minimize the amount of the background charges that may be established on the record medium.

It is understood that the present invention is not limited to the system specifically illustrated, but may be used in other electrostatic recording systems, such as where the recording electrodes are in the shape of the characters to be recorded. Many other variations, modifications and applications of the invention will be apparent to those skilled in the art, and it is intended that the invention be limited only as defined in the following claims:

I claim:

1. Electrostatic recording apparatus comprising a first electrode having a face thereof shaped in accordance with an electrostatic charge to be deposited on a charge-retentive record medium; means for feeding a charge-retentive record medium past said electrode face defining a recording electrical discharge gap therebetween; means for supplying discrete voltage pulses to said first electrode to produce a discrete electrostatic discharge therefrom onto said record medium shaped in accordance with the face thereof; means providing an auxiliary electrical discharge gap in the vicinity of said recording electrical dis-

charge gap; said latter means comprising a second electrode and a third electrode both of which are separate and distinct from said first electrode; and means for producing an electrical discharge between said second and third electrodes at the time voltage pulses are applied to said first electrode; said second and third electrodes being spaced from said first electrode sufficiently close to promote an electrical discharge from said first electrode onto said record medium but being oriented in shielded relation with respect to the record medium so as not to produce electrostatic discharges therefrom directly onto the record medium.

2. Electrostatic recording apparatus as defined in claim 1 wherein said auxiliary electrodes forming said auxiliary electrical discharge gap are carried by a separate member, one of the auxiliary electrodes being pin-shaped and having a resistor in series therewith.

3. Electrostatic recording apparatus as defined in claim 1 wherein said auxiliary electrodes forming said auxiliary electrical discharge gap are carried on a separate member, said separate member being disposed out of alignment with said recording electrical discharge gap; and means for reflecting the irradiations generated by said auxiliary electrical discharge gap into said recording electrical discharge gap.

4. Electrostatic recording apparatus as defined in claim 1 wherein said auxiliary electrodes forming said auxiliary electrical discharge gap are carried by their respective recording electrode, but spaced therefrom; and means interposed between said auxiliary electrodes and said charge-retentive record medium for shielding said record medium from the charges generated by said auxiliary electrodes in said auxiliary electrical discharge gap.

5. Electrostatic recording apparatus comprising a line of recording heads each having at least one recording electrode; means for feeding a charge-retentive record medium past a face of said recording electrodes defining recording electrical discharge gaps therebetween; means for supplying discrete voltage pulses to said recording heads to produce a discrete electrostatic discharge from each recording electrode onto said record medium shaped in accordance with face of said recording electrode; means providing an auxiliary electrical discharge gap in the vicinity of each of said recording electrical discharge gaps; said latter means comprising a pair of auxiliary electrodes for each recording head, said auxiliary electrodes being separate and distinct from the recording electrodes of their respective recording head; and means for producing an electrical discharge between said auxiliary electrodes at the time voltage pulses are applied to said recording heads; said auxiliary electrodes being spaced from said recording electrodes a relatively large distance when compared to the spacing between said auxiliary electrodes, but sufficiently close to promote an electrical discharge from said recording electrodes onto said record medium; said auxiliary electrodes being oriented in shielded relation with respect to the record medium so as not to produce electrostatic discharges directly onto the record medium.

6. Electrostatic recording apparatus as defined in claim 5 wherein said auxiliary electrodes forming said auxiliary electrical discharge gaps are carried by an elongated stick, one of the pair of each auxiliary electrode pairs being pin-shaped and having a resistor in series therewith, the other electrode of all the auxiliary electrode pairs being an elongated electrode common to all said auxiliary electrode pairs.

7. Electrostatic recording apparatus as defined in claim 5 wherein said auxiliary electrodes forming said auxiliary electrical discharge gaps are built into their respective recording heads, but spaced from their respective recording electrodes; and wherein said apparatus further includes means interposed between said auxiliary electrodes and said charge-retentive record medium for shielding said record medium from the charges generated by said

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auxiliary electrodes in said auxiliary electrical discharge gaps.

8. Electrostatic recording apparatus comprising a line of recording heads each having at least one recording electrode; means for feeding a charge-retentive record medium past a face of said recording electrodes defining recording electrical discharge gaps therebetween; means for supplying discrete voltage pulses to all said recording heads simultaneously to produce a discrete electrostatic discharge from each recording electrode onto said record medium shaped in accordance with the face of the recording electrode; means providing an auxiliary electrical discharge gap in the vicinity of each of said recording electrical discharge gaps; said latter means comprising a pair of auxiliary electrodes for each recording head, said auxiliary electrodes being separate and distinct from the recording electrodes of their respective recording head; and means for producing an electrical discharge between said auxiliary electrodes sequentially one at a time at the time voltage pulses are applied to all said recording heads simultaneously; said auxiliary electrodes being spaced from said recording electrodes a relatively large distance when compared to the spacing between said auxiliary electrodes, but sufficiently close to promote an electrical discharge from said recording electrodes onto said record medium; said auxiliary electrodes being oriented in shielded relation with respect to the record medium so as not to produce electrostatic discharges directly onto the record medium.

9. Electrostatic recording apparatus comprising a line of recording heads; each of said recording heads comprising a matrix of pin-shaped recording electrodes each having a face thereof adapted to record a dot-shaped electrostatic charge on a charge-retentive record medium; means for feeding a charge-retentive record medium past said electrode faces defining recording electrical discharge gaps therebetween; means for supplying discrete voltage pulses to preselected ones of said recording electrodes of each head, to provide a pattern of dot-shaped charges in accordance with the information to be recorded; means providing an auxiliary electrical discharge gap in the vicinity of each of said recording electrical discharge gaps; said latter means comprising a pair of auxiliary electrodes both of which are separate and distinct from said recording electrodes; and means for producing an electrical discharge between said auxiliary electrodes at the time voltage pulses are applied to said recording electrodes; said auxiliary electrodes being spaced from said recording electrodes a relatively large distance when compared to the spacing between said auxiliary electrodes, but sufficiently close to promote an electrical discharge from said recording electrodes onto said record

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medium; said auxiliary electrodes being oriented in shielded relation with respect to the record medium so as not to produce electrostatic discharges therefrom directly onto the record medium.

10. Electrostatic recording apparatus comprising a line of recording heads; each of said recording heads comprising a matrix of at least one column of pin-shaped recording electrodes each having a face thereof adapted to record a dot-shaped electrostatic charge on a charge-retentive record medium; said recording heads further including a bar electrode cooperable with said column of pin electrodes; means for feeding a charge-retentive record medium past said recording electrode faces defining recording electrical discharge gaps therebetween; means for supplying discrete voltage pulses to preselected ones of said recording electrodes of all said heads simultaneously, to provide a pattern of dot-shaped charges in accordance with the information to be recorded; means for supplying a voltage pulse to the bar electrode of each head sequentially and in coincidence with said information pulses; means providing an auxiliary electrical discharge gap in the vicinity of each of said recording electrical discharge gaps; said latter means comprising a pair of auxiliary electrodes both of which are separate and distinct from said recording electrodes; and means for producing an electrical discharge between said auxiliary electrodes at the time voltage pulses are applied to said recording electrodes; said auxiliary electrodes being oriented in shielded relation with respect to the record medium so as not to produce electrostatic discharges therefrom directly onto the record medium.

11. Electrostatic recording apparatus as defined in claim 10 wherein the means for producing an electrical discharge between said auxiliary electrodes comprises means for pulsing said auxiliary electrodes sequentially one at a time in coincidence with the pulsing of said bar electrodes.

12. Electrostatic recording apparatus as defined in claim 10 wherein the means for producing an electrical discharge between said auxiliary electrodes comprises means for pulsing said auxiliary electrodes simultaneously all at the same time with each application of information pulses to preselected ones of the recording electrodes.

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