

Oct. 11, 1960

H. EPSTEIN

2,955,894

PAGE PRINTING APPARATUS

Filed April 5, 1957

4 Sheets-Sheet 2

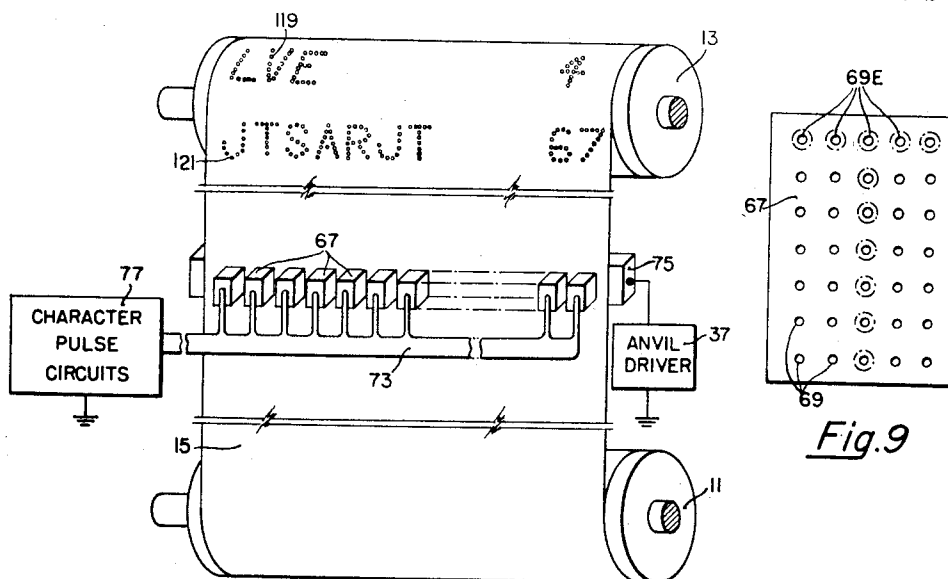


Fig. 7

Fig. 9

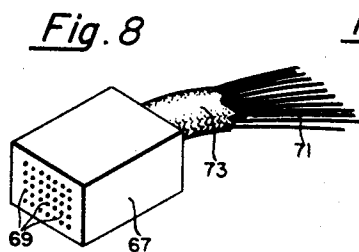


Fig. 8

Fig. 6

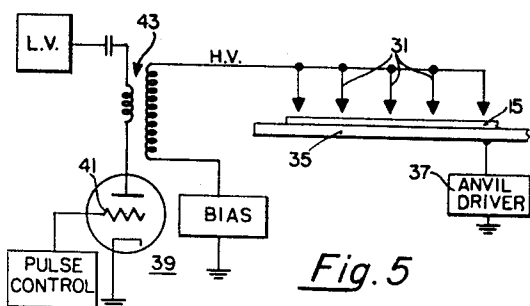
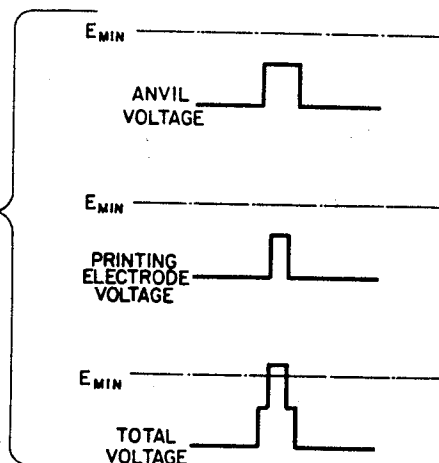


Fig. 5

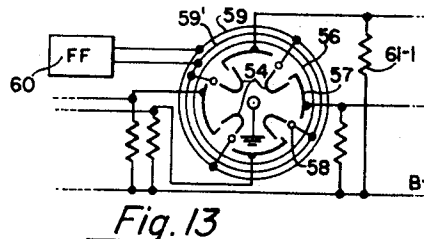


Fig. 13

INVENTOR.
HERMAN EPSTEIN

BY

Ralph K. Buel
AGENT

Oct. 11, 1960

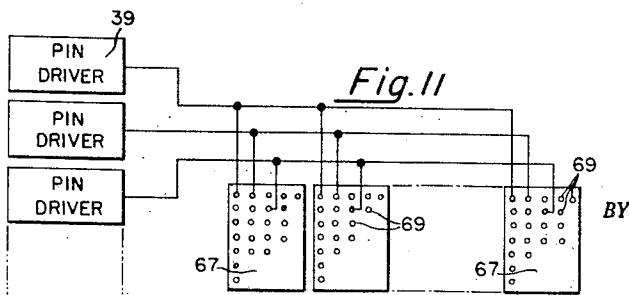
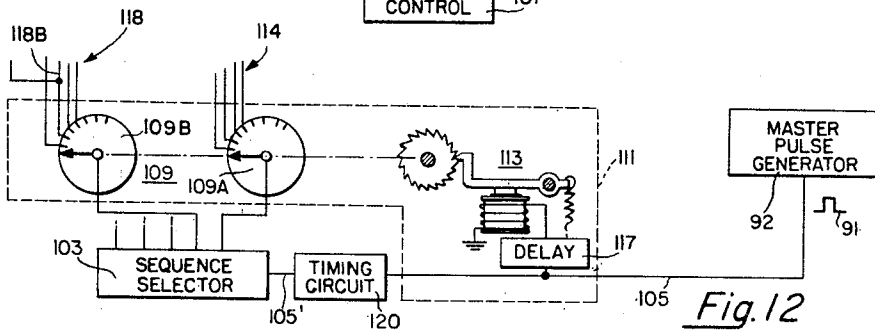
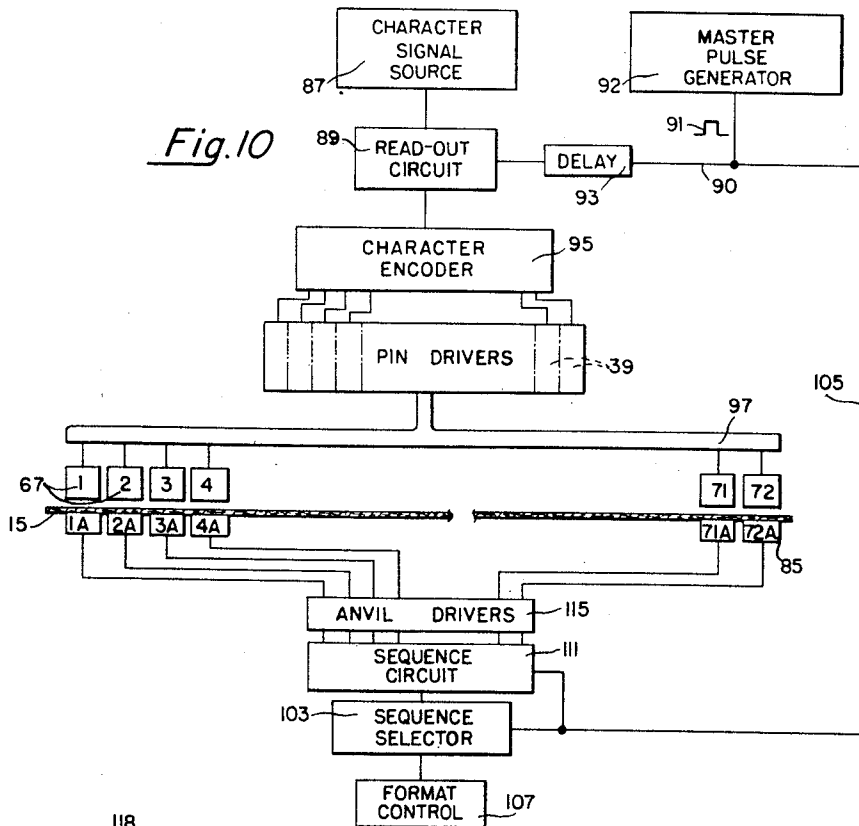
H. EPSTEIN

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PAGE PRINTING APPARATUS

Filed April 5, 1957

4 Sheets-Sheet 3



INVENTOR.

HERMAN EPSTEIN

BY

Ralph A. Bonnell
AGENT

Oct. 11, 1960

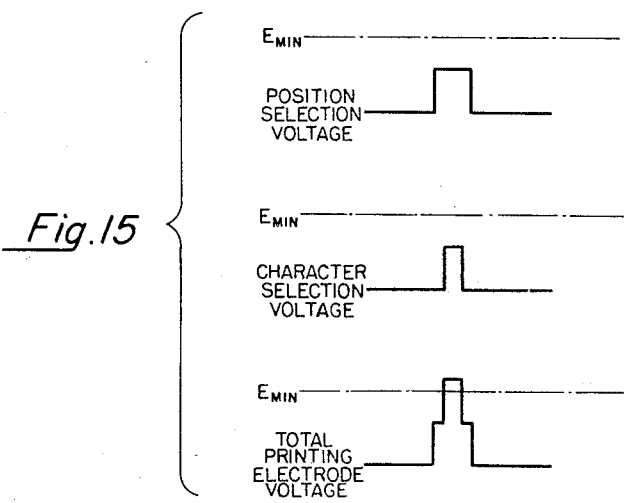
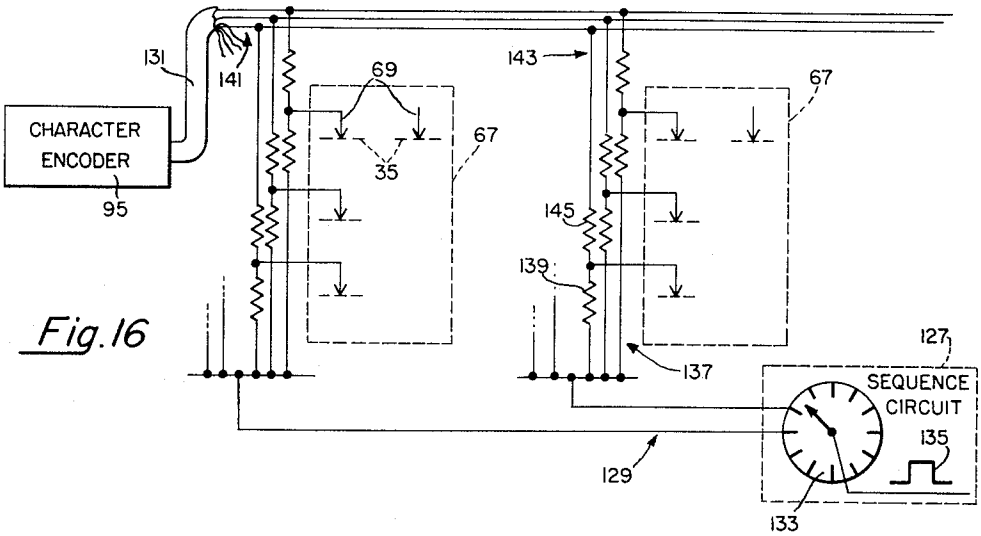
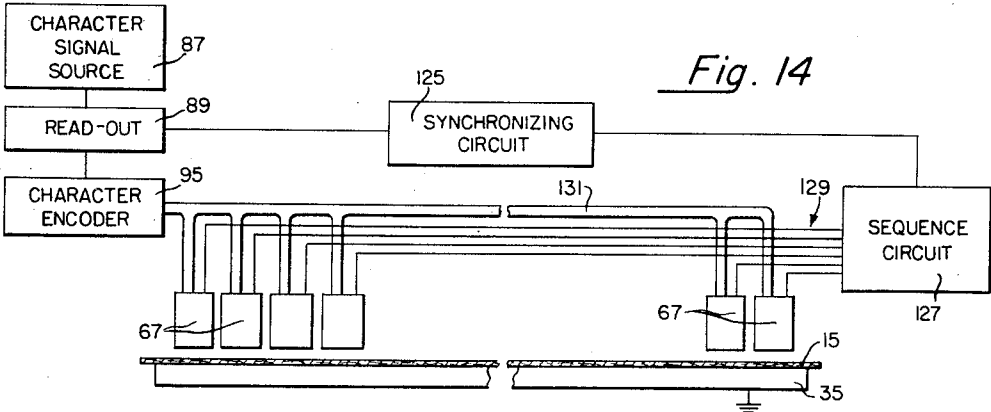
H. EPSTEIN

2,955,894

PAGE PRINTING APPARATUS

Filed April 5, 1957

4 Sheets-Sheet 4



BY

INVENTOR.
HERMAN EPSTEIN

Ralph H. Bonnell
AGENT

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2,955,894

PAGE PRINTING APPARATUS

Herman Epstein, West Chester, Pa., assignor to Burroughs Corporation, Detroit, Mich., a corporation of Michigan

Filed Apr. 5, 1957, Ser. No. 650,890

8 Claims. (Cl. 346—74)

This invention relates to improvements in page printing apparatus, with particular reference to page printers of the so-called "electrographic" type. The present application for patent is related to and includes subject matter in common with a similarly entitled joint application of Herman Epstein and Robert J. Phelps, Serial No. 642,872, filed February 27, 1957, assigned to the present assignee, now United States Patent 2,919,171.

In the electrographic printing process the indicia to be printed, such as letters, lines, dots, etc., are first formed as invisible electrostatically charged surface areas of a recording medium by means of silent electrical discharges from suitably shaped and suitably positioned electrodes. Subsequently these charged areas are rendered visible by the application of finely divided pigmented powder to the surface of the medium as a developing agent or "ink," the powder being held to the medium by electrostatic attraction substantially only over the charged areas. The powder image thus obtained is fixed in any of various available ways, to produce a permanent record. Further details of the electrographic process and of means for practicing it are disclosed in copending applications Serial No. 320,592, filed November 14, 1952, now United States Patent 2,919,170, and Serial No. 443,646, filed July 15, 1954, both assigned to the assignee of the present invention; and also, in a paper jointly authored by the present applicant, and an associate, published in part IV of the Institute of Radio Engineers Convention Record of 1955.

The type of apparatus described in the above cited patent applications and publication is particularly suited to the high speed production of a printed record which does not vary greatly in format in different portions of the record. A strip printer which prints characters more or less continuously in a single column or relatively few columns extending in the direction of transport of the medium, is an example of this class of apparatus. (The term "character" is used broadly herein to refer to any printed marking employed, singly or as a component of a group of markings, to convey information. In a more specific sense it is used to refer to an alphanumeric character.) When page printing is required, including printing on continuous webs of considerable width, more complex problems usually are presented, such as the line-by-line printing of characters in positions selected from a large number of possible character printing positions in a line of text and in relationships which may vary from line to line. An output printer for an electronic digital computer is an example in point.

High operating speed, which is a generally desirable feature in printing apparatus, becomes of critical importance in apparatus for directly recording the output of electronic computers, telemetering receivers, and the like, because of the high rate at which data for printing are produced by such equipment. In certain prior art output printers wherein displacements of movable members or material masses occur in the printing operation, the mechanical inertia of such members or masses and the

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transit times involved in their required movements are factors inherently limiting operating speed. Printing by means of electrostatic charges, as carried out by the electrographic apparatus of the present invention, is free from these handicaps. The relatively high current requirements and the deterioration of electrodes encountered in the operation of spark recorders also are avoided in a system in accordance with present invention since, with the silent, non-arcing discharges employed, there is no complete breakdown of the atmosphere such as occurs when a spark or arc passes between a pair of electrodes. For the same reason de-ionization time is not a limiting factor.

The actual printing operation is not the only one which may involve delays or which may limit operating speed. Delays also may occur in connection with character selection and, in the case of page printers, the selection of character printing positions in a line of such positions across a page or web of page width. Certain earlier electrostatic printing devices although having the advantage of rapid character printing have the disadvantage that character selection involves the mechanical displacement of character printing members, this operation, therefore, being subject to the above cited limitations associated with such displacements. For example, in one such device an electrode wheel is employed bearing a plurality of raised type faces around the periphery thereof from which electrical discharges can be produced for printing purposes. The selection of a desired one of these type faces for printing in general involves a delay while the wheel is rotated through the necessary angle to bring the selected type face into printing position. In the presently disclosed apparatus, by way of contrast, the recording medium may be the only displaceable member. The operations of character selection, printing position selection and printing all can be carried out by electrically operating on stationary members. In the interest of simplifying the explanation of the principles of the invention, however, in some instances mechanical equivalents of certain adjunct electrical means, such as switches, are shown or referred to herein.

It is an object of the invention to provide page printing apparatus capable of operating at high speed and which inherently has a high degree of flexibility as to the format of the printed matter.

It is another object to provide high-speed page printing apparatus for line-by-line printing, wherein the characters or indicia to appear in a line of text may be rapidly selected and printed in any desired grouping and according to any desired sequence of characters or groups thereof.

It is another object to provide high speed page printing apparatus wherein the printing of a character is contingent upon the coincidental actuation of two cooperative and independently controllable stationary members, as by the application of a voltage pulse to each.

It is another object to provide electrographic page printing apparatus having stationary pin-type printing electrodes which may be selected singly or in groups for printing a variety of indicia in selected printing positions, together with independent printing control means therefor.

It is another object to provide electrographic page printing apparatus wherein the position in which a character is printed is selected from a group of printing positions each having stationary printing means variably operable to print different characters and all of which may be simultaneously conditioned to print the same character.

It is another object to provide electrographic printing apparatus for printing an array of characters on a displaceable medium in readily controlled selected relation-

ship both transversely and longitudinally of the direction of displacement of the medium.

It is another object to provide electrographic printing apparatus wherein distinct and independently controllable stationary means are provided respectively to set up a condition for the printing of a character in a selected position and to cause the printing of said character in said position.

It is another object to provide electrographic page printing apparatus wherein aligned electrode matrix printing heads are provided for printing a line of text, each variably energizable for character selection and each associated with an independently energizable means for printing position selection.

Other objects and advantages of the invention are brought out in the following specification, to be considered in connection with the appended drawings in which:

Fig. 1 is an end elevation of an electrographic printer, in simplified form, illustrating basic features of such apparatus;

Fig. 2 is a perspective view, with added electrical features, of an electrographic page printer in accordance with the principles of the invention and conforming, generally, to the arrangement of Fig. 1 but omitting certain portions thereof, wherein a single row of pin-type printing electrodes is employed;

Fig. 3 illustrates a modification of the printing circuit of Fig. 1, in schematic form;

Fig. 4 illustrates another modification of the printing circuit of Fig. 1, also in schematic form;

Fig. 5 is schematic diagram of a pin electrode driver circuit;

Fig. 6 is series of wave diagrams, for purposes of explanation;

Fig. 7 is perspective view, with added electrical features, of a modification of the printer of Fig. 1, in which a row of matrix-type printing heads is employed;

Fig. 8 is a perspective view of one of the printing heads of Fig. 7;

Fig. 9 is an end view, to an enlarged scale, of the head of Fig. 8, with indications of energized electrodes therein;

Fig. 10 shows a portion of a circuit for an electrographic page printer, in block diagram form;

Fig. 11 shows a driver circuit for interconnected pin electrodes in a plurality of matrix printing heads;

Fig. 12 is a schematic diagram showing in detail certain features of the circuit of Fig. 10;

Fig. 13 is a circuit diagram including an electron beam switching tube;

Fig. 14 shows a modification of the circuit of Fig. 10 in which provision is made for applying coincident pulses to the printing heads, only;

Fig. 15 is a series of wave diagrams, for purposes of explanation; and

Fig. 16 is a circuit diagram showing the interconnection of the electrodes in the printing heads of Fig. 14.

In the operation of all modifications of the invention disclosed by way of illustration herein, printing of a latent electrostatic image on a charge-retentive record medium occurs when a suitable difference of potential is produced between a pair of mutually insulated and spaced electrode means (individual electrodes or electrode assemblies) relatively positioned for charging the medium. In most instances printing results from the application of two independently controlled voltage pulses, in coincidence, to these two electrode means, respectively. One means of the pair, however, may, under certain conditions, be held at a constant potential as the other is pulsed.

In one modification the paired electrode means above referred to may comprise, on one side of a displaceable record sheet or continuous web, either a single pin-shaped electrode selectable for energization from a line of such

electrodes extending laterally across the sheet or a combination of such electrodes extending laterally across the sheet or a combination of such electrodes selectable for energization from the electrode matrix of a matrix-type printing head (which may itself be an element of a line of such heads) with the other electrode means of the pair constituted by a base electrode or "anvil" on the opposite side of the sheet and commonly opposed to all printing electrodes.

In another arrangement, instead of an anvil common to a complete line of pin electrodes or of matrix printing heads, either individual anvils for the several printing electrode means (whether individual pins or combinations of pins) or anvils common to groups of such means of less than printing line length are provided.

Both of the above electrode arrangements are operated according to the coincident voltage method of energization earlier referred to herein. In this method two coincident pulses are required to print a character or group of characters, neither pulse alone being of sufficient amplitude to effectively charge the medium. For example in one arrangement the anvil, instead of being held at a constant potential, as has been the case in the operation of prior art systems, receives a voltage pulse which, added to a voltage pulse of less than printing value applied to the opposed printing electrode means makes up the necessary total printing voltage.

In another arrangement two independently controllable pulses are simultaneously applied to a printing electrode or electrodes, with the anvil maintained at a constant potential. This two-pulse method of printing, in whatever way applied, provides a second control, or second degree of freedom, permitting character printing position selection to be independent of the selection of the particular character printed, thus making possible a wide variety of arrangements for line-by-line printing of alphanumeric characters, of graphs, etc., certain of which are described below.

Referring, now, to the drawings, Fig. 1 shows in simplified form a system embodying basic features of the electrographic printing process. In this figure there is seen a supply roll 11 and a take-up roll 13 between which a recording medium or web 15 is transported (by means not shown in this figure) either continuously or in steps corresponding to a desired spacing of successive lines of the printed material. At station 17 any previously accumulated electrostatic charge on the record surface of the unprinted web is discharged, as by corona means 19, such means being commercially available. At printing station 21 this charge-free surface receives a patterned electrostatic charge constituting a latent image of the indicia later to be made visible. For this purpose there are provided at station 21 electrode assemblies which may be of various types, as illustrated in other figures and described in detail hereinafter. At inking station 23 web 15 passes through a receptacle containing finely divided pigmented inking powder 25, the powder adhering to the charged areas by electrostatic attraction. The inked image is rendered permanent upon the passage of web 15 past heating means 27, which partially softens either the inking powder or the record surface of web 15, or both, depending on which of these elements comprises material having thermoplastic properties. Passage between pressure rolls 29 ensures permanent adhesion of the ink particles to the medium, upon re-hardening of the softened material. After printing, web 15 which may be of page width, may be severed, if desired, to provide separate pages of printed material.

Fig. 2 shows an electrographic printer, according to the invention, for printing alphanumeric characters, plotting graphs, etc., including means, here illustrated as motor 30 for transporting continuous recording web 15. In particular, an arrangement of electrodes and associated apparatus is shown at printing station 21 in which a single row of spaced and mutually insulated pin-type

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printing electrodes 31 is provided, the electrodes having aligned discharge surfaces which are positioned closely adjacent the record surface of web 15. If this web has a paper base, the record surface may be constituted by a polyethylene coating, for example, which has both charge-retentive and thermoplastic properties. The mutual spacing of pins 31, laterally of the web, may be very small, of the order of 0.020 inch, to provide high resolution and an appearance of continuous lines, instead of recognition of the individual dots printed by the electrodes, in the visible image, here illustrated (with exaggerated spacing of the dots) at the left of web 15 as a graph and at the right as assemblies of dots forming the letter "T," in two reading positions. Instead of projecting beyond the surface of insulating support 33, as shown in Fig. 2 for clarity of illustration, the pin electrodes may be flush therewith. The spacing of the discharge surfaces of the pins from the record surface will usually range from less than a thousandth to a few thousandths of an inch. Actual contact with this surface, however, is not excluded.

On the opposite side of web 15 and having an electrode surface normally in contact with the non-record surface thereof there is positioned a base electrode or anvil 35 which, in the arrangement of Fig. 2 is common to all electrodes 31. Anvil 35 preferably is insulated from the frame of the apparatus for the application of a potential thereto differing from ground or reference potential. Printing occurs when a sufficient total difference of potential exists between anvil 35 and one or more electrodes 31, as a result of coincident voltage pulses applied to these opposed electrode means by suitable drivers 37 and 39, respectively, to produce a silent, non-arc ionizing discharge causing the record surface of web 15 to acquire an electrostatic charge over areas roughly corresponding to the discharge surfaces of the active printing electrodes. It has been found that, under given conditions, there is a minimum value for this difference in potential which must be equalled or exceeded to insure reliable printing, that is to produce charges which are of sufficient strength to result in later satisfactory inking. This minimum value depends on the size and shape of the printing electrodes, the condition of the discharge surface, the atmosphere in which the discharge occurs, the record surface, and other factors. A representative value for discharges from pin electrodes of the above mentioned size and with the above mentioned spacing from the medium, may be around 1000 volts.

The relative voltage values involved in the coincident voltage method of printing are illustrated in Fig. 6 in each of the three wave diagrams of which the same assumed value of minimum printing voltage is represented by the position, above a base line, of a broken line designated E_{min} . In printing, a voltage pulse of lesser amplitude than E_{min} is applied to anvil 35 (top line of Fig. 6), as by driver circuit 37 (Fig. 2), and a voltage pulse, also of lesser amplitude than E_{min} is applied to one or more of printing electrodes 31 (middle line), as by individual driver circuits 39. These two pulses are polarized to be additive in producing a difference in potential between the active electrodes 31 and anvil 35 and their sum exceeds E_{min} , so that when co-existent for a sufficient interval, of the order of a microsecond or less, printing of the latent electrostatic image occurs. This is illustrated on the bottom line of the figure.

The diagrams of Fig. 6 are for the purpose of illustrating the addition of pulse amplitudes, only, in the case where the two coincident pulses are applied to the printing electrode or electrodes and anvil, respectively, without implying the directions of departure of the pulses from ground or other reference potential. It is sometimes desirable, for more precise control of the time of printing, to condition the apparatus for printing by the application of one of the necessary two pulses in advance of the other, actual printing then occurring with the advent of the sec-

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ond pulse. Prolongation of the first pulse beyond the occurrence of the trailing edge of the second pulse also may be desirable. These features are illustrated in the diagram on the bottom line of Fig. 6. Except for considerations applying to a particular design, it is immaterial which element, printing electrode or anvil, receives the first or the prolonged pulse.

In certain previously disclosed electrographic printing systems, for example as described in application Serial No. 443,646, the anvil is maintained at a constant reference potential, usually so-called "ground" potential, and a constant bias relative thereto, less than the minimum printing voltage, is applied to the printing electrodes. An incremental voltage, to raise the total voltage above this minimum, is then applied to the printing electrodes for printing purposes. Since the bias in these systems is a steadily applied voltage such a system is not as flexible in the matter of printing control as the two-pulse system of the present invention, which has other advantages over a bias system of operation later to be referred to herein.

When the apparatus of the invention is used for plotting the values of variable data, as a curve made up of discrete dots, seen in Fig. 2 at the left of web 15 (the individual dots in this case being the printed "characters"), data quantizing means will precede drivers 39 to select the leads 40 to be energized to supply energization to pin electrodes 31 in positions laterally of web 15 respectively corresponding to the data values to be plotted.

Fig. 5 shows one form of driver circuit 39 which may be used to supply a relatively high voltage pulse (say, 500 volts) to one or more pin electrodes in parallel. In this circuit low voltage control is exercised by way of the grid of triode 41, to vary the impedance of and hence the current passed by that device, while voltage step-up occurs by way of plate circuit transformer 43. Similar circuit means may be employed for anvil driver 37.

Two modifications of the electrode arrangement and associated circuitry of Fig. 2 are shown, schematically, in Figs. 3 and 4, respectively. In Fig. 3 individual anvils 45 cooperate with pin electrodes 31, respectively, each anvil having its own driver 37. In addition there are shown in this figure, in block form, pin selection circuits 47 and anvil selection circuits 49, the former circuit also being applicable to the arrangement of Fig. 2, preferably ahead of drivers 39. These are switching circuits which may take various known forms.

While the electrode arrangement of Fig. 2 provides two choices of printing procedure, (a) printing from a sequence of individual pins 31 by repeated excitation of common anvil 35 (series printing) or (b) printing from a plurality of pins 31 simultaneously, with a single pulse applied to anvil 35 (parallel printing), the arrangement of Fig. 3 provides further choices including, (c) simultaneous excitation of a plurality of one type of electrode means (pins or anvils) with control over the positions and the sequence in which printing occurs (selective printing) through control of the excitation of the other type of electrode means (anvils or pins). For instance, employing the timing of the pulses shown in Fig. 6, anvil voltage initially may be applied to any selected group of anvils 45 in consecutive or non-consecutive positions in the line of anvils. Control of the application of printing electrode voltage then affords control of the printed image both as to position laterally of web 15 and as to time of formation. The latter feature, in conjunction with transport of the web, continuous or line-by-line, affords control of the position of the image longitudinally of the web. It will be apparent, therefore, that through the appropriate operation of selector circuits 47 and 49 great flexibility in the printing of sequences and combinations of dots, and of the more complex characters formed thereby, can be attained.

The circuit of Fig. 4 represents an arrangement whereby a considerable decrease in the number of driver-circuits (with respect to the arrangement of Fig. 3) can be

attained without undue sacrifice in flexibility of operation. In this case anvils 55 each are common to a group of printing electrodes 31, thereby effecting one portion of the saving in driver circuits. In addition, the printing electrodes in like-numbered positions in each group thereof are connected together for excitation from a common driver, thus effecting a second saving in driver circuits. Fig. 4 illustrates a circuit for printing a line of text having sixteen character positions making use of four groups of four pin electrodes each, with a single anvil for each group. Therefore, only four pin driver circuits, each exciting four pins, and four anvil driver circuits are required, a total of eight such circuits as compared to thirty-two in the case of apparatus of similar printing capacity employing the connections of Fig. 3. The saving in drivers becomes greater as the number of printing positions in a line increases. Assuming, for simplicity, that n , the number of printing positions in a line, is a perfect square and that the pin group served by a single anvil includes n pins; then the total number of drivers becomes $2n$, as compared to $2n$ in the case of the individual drivers of Fig. 3. Since voltage pulses, only, are supplied, with relatively little power, the advantage of the saving in driver circuits more than offsets the disadvantage of the greater number of elements excited by each such circuit.

In Fig. 4 the pin and anvil selection means 56 and 56', respectively (corresponding in part to circuits 47 and 49 of Fig. 3), are shown as electron beam switching tubes of the type disclosed in U.S. Patent No. 2,764,711, issued September 25, 1956, to Saul Kuchinsky, wherein a cathode-formed electron beam is switched between a plurality of target electrodes 57 under the control of switching electrodes 58, individual to the several beam positions. Switching times of the order of a fraction of a microsecond are attainable with these tubes. In the figure, for simplicity, the means supplying positive voltages to targets 57 and to beam forming electrodes 54 (so-called "spades") are omitted. A more detailed showing of such a tube having four beam positions, and of associated circuitry, is to be found in Fig. 13. A commercial form of beam switching tube suitable for use in the present circuit is manufactured by the Electronic Tube Division of Burroughs Corporation, Plainfield, N.J.

In the more detailed switching circuit of Fig. 13 beam switching electrodes 58 are shown connected in alternation to a pair of ring busses 59, 59' which may be pulsed in repeated sequence by the output of a flip-flop 60. As described in U.S. Patent No. 2,721,955, issued October 25, 1955, also relating to beam switching tubes of the type illustrated herein, this results in the electron beam of the tube being rotated intermittently to energize and complete the circuit of targets 57 in turn. Output pulses may be developed as the voltage drop external target circuit impedances, such as impedance 61-1. When switching according to the positional sequence of the targets is not desired, the beam switching electrodes 58 may be selectively energized in random sequence, as suggested by independent anvil switching leads 62, two, only, of which are shown in Fig. 4, the switching beam being capable of jumping from one stable position to a non-adjacent position.

As previously described and as more particularly illustrated in Fig. 2, the elemental dots printed from a row of pin electrodes in the operation of any of the foregoing arrangements may be grouped to form more complex characters, including letters and numerals, as well as dotted lines such as graphs of data, by suitable excitation of the pins with respect to their positions and to time. An arrangement often requiring less circuitry, particularly for printing alphanumeric characters, is shown in Fig. 7 wherein instead of a row of single electrodes a row of printing heads 67 is provided each comprising a matrix of pin-type electrodes. A perspective view of one type of printing head 67 is shown in Fig. 8. This particular type of head comprises a plastic encapsulated assembly of

thirty-five pin-type printing electrodes 69 arranged in a 5 x 7 matrix, the individual electrodes of which may be simultaneously excited in combinations suitable to print desired complex characters. For instance, electrodes 69E are ringed in the enlarged end view of head 67 in Fig. 9 to indicate that these would be excited in this design of head, to print the letter "T." The pin spacing in one form of head extensively used is 0.017 inch in each direction, the pins being 0.003 inch in diameter. This permits the printing of alphanumeric characters of approximately upper case typewriter size. Further details of printing heads suitable for use in the present apparatus and to methods of manufacture thereof, are to be found in co-pending applications Serial Nos. 609,431, 631,194, and 631,211 (now abandoned), filed September 12, 1956, September 28, 1956, and September 28, 1956, respectively. Individual connecting wires 71 are provided for external interconnection of the pins, which may be grouped in a cable 73. Common anvil 75 of Fig. 7 has a dimension in the direction of the travel of web 15 commensurate with the corresponding dimensions of heads 67 and is driven or pulsed, as in Fig. 2, by a driver circuit 37.

The energization or excitation of the electrodes of the matrix of a head 67 to print a letter, etc., includes a selection of the desired character or the generation of a signal characteristic thereof, the encoding of this character or character signal as a group of pulses suitable for energizing the matrix electrodes and the application of these latter pulses to the appropriate electrodes of a selected printing head. In Fig. 7 the means for performing these several functions are grouped as character pulse circuits 77. Details of circuits suitable for selecting and encoding characters in connection with electrographic printing with pin electrode matrix heads are to be found in previously cited application Serial No. 443,646. In addition to single character printing, the simultaneous excitation of a plurality of heads according to the same or different characters and the printing of these characters upon the occurrence of a single anvil pulse, which may be termed "parallel matrix head printing," is feasible with the arrangement of Fig. 7 and is comparable to parallel printing with the single row of pins of Fig. 2.

Still greater flexibility and speed of operation, with simpler control over the format of the printed matter, is attained by the use of an individual anvil for, or associated with, each of the printing heads 67, instead of a single anvil common to all the printing heads. Fig. 10 illustrates such an arrangement, employing individual anvils 85. This figure shows, in block diagram form, a character signal source 87, which may be a computer, a storage device, or other means for supplying data to be printed, the data being assumed for purposes of the following description to be printed alphanumeric characters. Read-out of a character signal from source 87 is accomplished by circuit 89. This circuit, which may comprise any of various known gating arrangements, is shown in the figure as being controlled by pulses derived from timing pulses 91 supplied by Master Pulse Generator 92, by way of delay circuit 93. Instead of control by a pulse from an independent master generator, read-out of a character signal or signals from circuit 87 may be under the control of a pulse generated at the termination of the printing of the previous character or combination of characters (by means not shown).

A character signal read from source 87 is suitably encoded for matrix head excitation by circuit 95 (reference again being made in this connection to application Serial No. 443,646) to supply pulses by way of driver circuits 39, to the conductors of cable 97 connecting, with the appropriate printing electrodes in the matrices of selected ones of heads 67. When the desired mode of operation calls for the simultaneous excitation of all printing heads 67 in a line of heads according to the same character, with independent selection of the position or positions in which this common character is printed, as

will be considered at this point, the connections of Fig. 11 are suitable, wherein pins 69 in corresponding positions in all heads 67 are interconnected, in parallel to a pulse driver 39 (three of the thirty-five such connections, only, being shown). When the selected character excitation (in itself ineffective to cause printing) is impressed on all of heads 67 by voltage pulses which are applied to the pin electrodes necessary to print the selected character, the position or positions, transverse of web 15, in which the character is printed, or established, and the sequence in which such printing occurs, where this is of significance, is determined, as before, by the anvil or anvils, to which the anvil pulses are applied.

A pulse 91 from Master Pulse Generator 92, or its equivalent, in addition to initiating the read-out of a character signal from source 87 is supplied to a Sequence Selector 103 by way of lead 105. This selector is a switching device which is operated by Format Control 107 to select, at the start of printing a line of text, the positions and the sequence of positions, such as one after another, or serially, in which printing is to occur in that line. Different pre-set printing sequences are provided by multi-position switches 109 in Sequence Circuit 111, of which switches 109A and 109B are seen in the detailed showing of that circuit in Fig. 12.

Format Control 107, in one mode of operation, senses (by means not shown) the beginning of a line of text as defined by the operation of an intermittent paper feed which advances web 15 in accordance with the spacing of the lines of the text, as mentioned hereinbefore. Such an intermittent web feed has been disclosed in copending patent application Serial No. 503,714, filed April 25, 1955, now United States Patent 2,858,131. Master Pulse Generator 92 normally is synchronized (at a sub-multiple frequency) with the operation of such paper feeding means.

Format Control 107, according to a pre-set program thereof, sets up a path by way of the switching means comprised by Sequence Selector 103 whereby the versions of pulses 91 arriving at said selector over lead 105' during the printing of an entire line of text are applied to a particular switch 109, for example switch 109A, in Sequence Circuit 111. In the printing of such a line, operation of this switch, which has stationary contacts equal in number to the number of printing positions in the line, distributes the pulses to the anvils 85 connected to the respective contacts thereof.

Fig. 12 shows an arrangement for Sequence Circuit 111 which is suitable for line-by-line printing at moderate speeds. Switches 109 are commonly driven by stepping magnet 113 which is actuated, by way of a branch of lead 105, by versions of the same pulses 91 which control the printing and printing position selection operations. In this case the pulses are delayed by circuit 117, as referred to below. When the received pulses of themselves are ineffective to operate magnet 113 directly, amplification may be employed.

Tracing the functions of a master pulse 91 in controlling the operation of the apparatus, the leading edge of such a pulse first triggers timing circuit 120 (Fig. 12, employed, as explained, when it is desirable for the pin and anvil pulses to have slightly different but overlapping periods) to generate the leading edge of an anvil excitation pulse (Fig. 6); then by way of lead 90 a version of the pulse, delayed by circuit 93, initiates and terminates read-out, by circuit 98, of a character signal from circuit 87, thereby determining the leading and trailing edges of the encoded character pulses applied to the appropriate pin electrodes of a printing head or heads. It is assumed in this description that the signal available from source 87 is of suitable duration for the foregoing mode of operation.

Some time after the occurrence of the trailing edges of the character-encoded printing head pulses, timing circuit 120 terminates the anvil pulse (Fig. 6). Subse-

quently, the original pulse 91, delayed by circuit 117 (Fig. 12) causes the operation of stepping magnet 113. Operation of switches 109 to new positions by this magnet occurs later than the occurrence of the leading edge of the delayed, magnet-operating version of pulse 91, due to the inertia of the armature of magnet 113 and associated driven members. Stepping switches having operating rates suitable for many printing applications, however, are commercially available. Magnet 113 having stepped the currently active switch 109 (switch 109A) to its next position, the apparatus is in condition to print the next character.

Operation of switch 109A causes the excitation of selected anvils 85, i.e., in sequence according to one arrangement of characters in a line of printing, by way of leads 114 and individual anvil driver circuits 115, with which leads 114 connect, while switch 109B provides a means for exciting anvils 85 to print a different arrangement of characters in a line, by way of leads 118 and drivers 115. Consecutive contacts on switches 109, which determine the positions of successively printed characters in a line, need not correspond to anvils 85 in consecutive positions in the line. Thus, with a suitable number of suitably connected switches 109 to provide selected arrangements of characters in a line of text and with the programming of these different arrangements by Format Control 107 (operating by way of Sequence Selector 103), any desired distribution of characters on a page or along a continuous web may be attained. The term "character" here may be taken in its broad sense, previously mentioned, to include a single dot. In place of mechanically operated switches 109, equivalent high speed electronic switching means are available, for example, the electron beam switching tubes previously described.

As illustrations of different arrangements of characters in a line of text which can be printed by the means of Fig. 10, two lines of characters, 119 and 121, are shown in Fig. 7. Line 119 may be considered, for example, to be printed with switch 109A controlling the anvil excitation, by way of leads 114, while leads 118 from switch 109B may provide the connections for printing line 121. It will be noted that the letter "T" occurs twice in line 121 and that lead 118B (Fig. 12) is shown branched to provide for the simultaneous excitation of the anvils in the two positions in which this letter is printed, all heads 67 at the instant of printing being excited to print a "T."

Throughout this specification mention has been made of the printing of dots from pin-shaped electrodes. While the production of a dot-shaped charged area on the recording medium might, at first sight, appear to follow automatically from the form of the discharge surface of such an electrode, in practice, under certain conditions, it has been found necessary in order to secure good definition and limit the spreading of the charged areas, to cause the printing discharge to occur in a specially prepared atmosphere, specifically one comprising an electronegative gas. This feature of electrographic printing is disclosed in co-pending application Serial No. 478,602, filed December 30, 1954, now United States Patent 2,931,688, in the names of F. Innes, H. Epstein and R. Phelps.

Mention has been made hereinbefore of systems in which a constant bias, supplemented by a print pulse for printing control, is applied to the printing electrodes, only, the anvil being held at ground or reference potential. This is in contrast to the division of the total printing voltage into two pulses which have so far been described herein as being separately applied to a printing electrode and anvil. In addition to greater flexibility, the independent pulsing of printing electrode and anvil has the advantage that the peak value of the switched pulses is lower with respect to ground than in the constant

bias circuit and also that there is, under certain conditions, a reduction in complexity of the associated circuitry.

Certain of these advantages also may be realized in a system in which the total printing voltage is the resultant of two coincident pulses which are applied to the same instead of to different electrodes, for example pulses of similar polarity applied to the printing electrodes while the anvil is held at a constant potential. Control of the occurrence of either pulse can, in such a system, be employed to control printing.

A portion of the printing circuit of an electrographic printer operating in the above manner is shown in Fig. 14. Here, synchronizing circuit 125 represents any suitable means for timing the relative occurrences of the two component pulses applied to the electrodes of printing heads 67, whose coincidence results in a pulse of printing amplitude. One form of such synchronizing means including a master pulse generator and associated circuit elements has been described with reference to Fig. 10.

The relative timing and amplitudes of the component printing pulses occurring in the operation of the circuit of Fig. 14 are illustrated by the wave diagrams of Fig. 15 which will be found to be similar in form to those of Fig. 6 but which represent pulses utilized in a different manner. Thus, the "Position Selection Voltage" of the top line of Fig. 15 represents a pulse of less than the minimum printing amplitude applied by Sequence Circuit 127 to any one of leads 129 and by way of the selected lead to all the pin electrodes 69 of a single printing head 67, or to a plurality of such heads when simultaneous multi-position printing of a character is called for. This determines the position or positions in which a character can be printed. The "Character Selection Voltage" of the middle line of Fig. 15 corresponds directly to the "Printing Electrode Voltage" of Fig. 6 and represents in this case the voltage applied by way of conductors in cable 131 only to those pin electrodes in a printing head in the requisite spatial grouping to print a selected character. In a preferred mode of operation for the arrangement of Fig. 14 similar character-defining electrode groups are energized simultaneously in a plurality or all of the heads 67 in a line of such heads, in similar manner to the method of operation described in connection with the arrangement of Fig. 10. The same considerations relating to the relative durations of the two component printing pulses and particularly to the relative occurrences of the leading edges thereof which have been discussed in connection with Fig. 6, apply to the pulses of Fig. 15. Driver and other circuits of minor significance, referred to elsewhere, are omitted from Fig. 14, for simplicity of illustration.

Circuit connections which permit the two component pulses making up the total printing voltage to be applied to the pin electrodes in the foregoing manner are illustrated in Fig. 16. Connections to three pin electrodes 69 in each of two heads 67, only, are shown and anvil 35 while actually continuous and commonly opposed to all electrodes 69, is indicated within the outlines of the two heads by discrete dashed line segments respectively adjacent the representation of these electrodes, again for simplicity of illustration.

Printing position and printing sequence in a line of characters is under the control of Sequence Circuit 127 corresponding generally in function to Sequence Circuit 111 of Fig. 10 and which may comprise any suitable switching device, as commutator 133 or an electronic version thereof, for applying Position Selection Voltage pulses 135 to leads 129 in sequence and at times determined by Synchronizing Circuit 125. The connection of a lead 129 to all of the pin electrodes of one printing head 67 is by way of individual branched leads, for example leads 137, each comprising a decoupling impedance 139.

The character-encoded signals supplied by Character Encoder 95, as noted, preferably energize like groups of

pin electrodes 69 in a plurality or all of heads 67 with the Character Selection Voltage. This occurs by way of a suitable number of leads 141 in cable 131 and individual leads branched therefrom to the appropriate printing electrodes, as leads 143 each comprising a decoupling impedance 145. Decoupling impedances 139 and 145 although shown for simplicity as single resistances, may take other forms and may be components of more complex networks, their function being to permit the simultaneous pulsing of a printing electrode 69 as a component of two different groupings of such electrodes, the character group and the positional group, without deleterious interaction between the groups.

For convenience the term "pin electrode" is used herein at certain points in the specification and claims to refer to an electrode capable of printing a small dot-shaped electrostatic image which images may be grouped to form representations of more complex indicia. This term is to be construed as including any electrode having a limited discharge surface capable of producing the stated result although the body portion thereof may depart from the shape of a cylindrical pin.

It will be understood, moreover, that the present invention may be embodied in many different structures, those disclosed herein being by way of illustration, only, and not by way of limitation.

What is claimed is:

1. In high speed electrostatic printing apparatus, the combination of: a plurality of similar stationary printing electrodes having the discharge areas thereof in surface alignment, said printing electrodes being arranged in a row with each electrode representing a printing position; anvil electrode means having positions thereof respectively opposed to said printing electrodes and similarly spaced from said discharge areas thereof to define a gap therebetween for the reception of a charge retentive recording medium; means for maintaining said anvil electrode means at a constant reference potential, the operating relationship of each printing electrode and the anvil electrode means being such that when an electrical field is established therebetween by a difference in potential exceeding a critical value, an electrostatic charge is produced on the charge retentive medium interposed therebetween; means for generating two series of voltage pulses both departing from said reference potential in the same direction, the pulses of each series having an amplitude corresponding to a difference in potential less than said critical value; means for controlling the relative occurrences of pulses respectively comprised by said two series to produce coincidence thereof, and connected to the pulse generating means for distributing such coinciding pulses in a given sequence to the electrodes of the printing position to thereby create a difference in potential between selected ones of said printing electrodes and the portions of said anvil electrode means respectively opposed thereto, said difference in potential exceeding said critical value thereof when due to coincident pulses of said two series and producing an electrostatic charged pattern on the charge retentive medium.

2. In a recording device comprising a multiplicity of recording heads each including a plurality of electrodes; at least one common electrode opposed to said recording heads with an air gap therebetween; means for feeding a recording medium in said gap; means for applying to those selected electrodes in each head appropriate to formation of a pattern representative of a particular symbol first potentials insufficient alone to produce an electrical discharge to an opposed common electrode; and means for applying to at least one selected head second potentials insufficient alone to produce an electrical discharge to an opposed common electrode, but sufficient to promote a non-disruptive electrical discharge to an opposed common electrode from only the vicinity of those electrodes to which said first potentials have been applied.

3. In recording apparatus, the combination of a plurality of electrode recording heads, each of said recording heads including a plurality of mutually insulated pin-type electrodes in the form of a matrix; at least one common electrode external to said heads and opposed to said pin-type electrodes with a gap therebetween; means for feeding a recording medium in said gap; means for maintaining said common electrode at a constant reference potential; means for applying first pulses simultaneously to pin-type electrodes in a plurality of said recording heads, the amplitudes of said pulses being insufficient alone with respect to the reference potential of said common electrode to effect a recording by said pin-type electrodes on said recording medium; and means for applying a second pulse to a selected recording head and in time coincidence with said first pulses, to thereby effect a recording on said recording medium by the agency of the pin-type electrodes in only said selected head.

4. Recording apparatus as defined in claim 3 wherein said last-named means applies said second pulse to the pin-type electrodes of said selected recording head.

5. In recording apparatus, the combination of a plurality of electrode recording heads, each of said recording heads including a plurality of mutually insulated pin-type electrodes in the form of a matrix; at least one common electrode external to said heads and opposed to said pin-type recording electrodes with a gap therebetween; means for feeding a recording medium in said gap; means for maintaining said common electrode at a constant reference potential; means for applying simultaneously to homologously situated pin-type electrodes of all said recording heads a first pulse tending to energize same in accordance with a spatial pattern representative of a character to be recorded, the amplitudes of said pulse being insufficient alone with respect to the reference potential of said common electrode to effect a recording by said pin-type electrodes on said recording medium; and means for applying a second pulse to at least one selected recording head and in time coincidence with said first pulses applied to the pin-type electrodes in all said recording heads to thereby effect a recording on said recording medium by the agency of the pin-type electrodes in only said at least one selected head.

6. In recording apparatus, the combination of a plurality of electrode recording heads, each of said recording heads including a plurality of mutually insulated pin-type electrodes in the form of a matrix; at least one common electrode external to said heads and opposed to said pin-type recording electrodes with a gap therebetween; means for feeding a recording medium in said gap; means for maintaining said common electrode at a constant reference potential; a first circuit including impedance means

for applying simultaneously to homologously situated pin-type electrodes of all said recording heads a first pulse tending to energize same in accordance with a spatial pattern representative of a character to be recorded, the amplitudes of said pulse being insufficient alone with respect to the reference potential of said common electrode to effect a recording by said pin-type electrodes on said recording medium; and a second circuit including impedance means for applying a second pulse to a selected recording head and in time coincidence with said first pulses applied to the pin-type electrodes in all recording heads, to thereby effect a recording on said recording medium by the agency of the pin-type electrodes in only said selected head.

7. In recording apparatus, the combination of a plurality of electrode recording heads, each of said recording heads including a plurality of mutually insulated pin-type electrodes in the form of a matrix; at least one common electrode external to said heads and opposed to said pin-type electrodes with a gap therebetween; means for feeding a recording medium in said gap; means for maintaining said common electrode at a constant reference potential; a source of character signals; means for encoding each character signals from said source in suitable form for energizing the pin-type electrodes of one of said electrode recording heads according to a spatial pattern representative of said character; means for distributing signals thus encoded to the pin-type electrodes of a plurality of said electrode recording heads; said encoded signals of themselves being ineffective alone with respect to the reference potential of said common electrode to effect a recording by the pin-type electrodes on said recording medium; and means for sequentially applying a further signal to said recording heads consecutively and in coincidence with said encoded signals to produce a serial recording on said recording medium of said encoded character signals by the electrodes of each recording head to which the said further signal is applied.

8. Recording apparatus as defined in claim 7 wherein the last-named means applies a pulse to the pin-type electrodes of each recording head in sequence.

References Cited in the file of this patent

UNITED STATES PATENTS

2,035,474	Hay	Mar. 31, 1936
2,035,475	Hay	Mar. 31, 1936
2,716,826	Huebner	Sept. 6, 1955
2,739,865	Wiley	Mar. 27, 1956
2,769,680	Beck	Nov. 6, 1956
2,771,336	MacGriff	Nov. 20, 1956
2,857,290	Bolton	Oct. 21, 1958