United States Patent [19]

Kittredge

[11] **3,918,567**

[45] **Nov. 11, 1975**

[54] **PROCESS PRINTING**

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[52] **U.S. Cl.** .... **197/1 R;** 101/93.04

[51] **Int. Cl.**[2] **B41J 3/05**

[58] **Field of Search**...... 197/1 R; 101/93 C; 178/30; 346/50, 78

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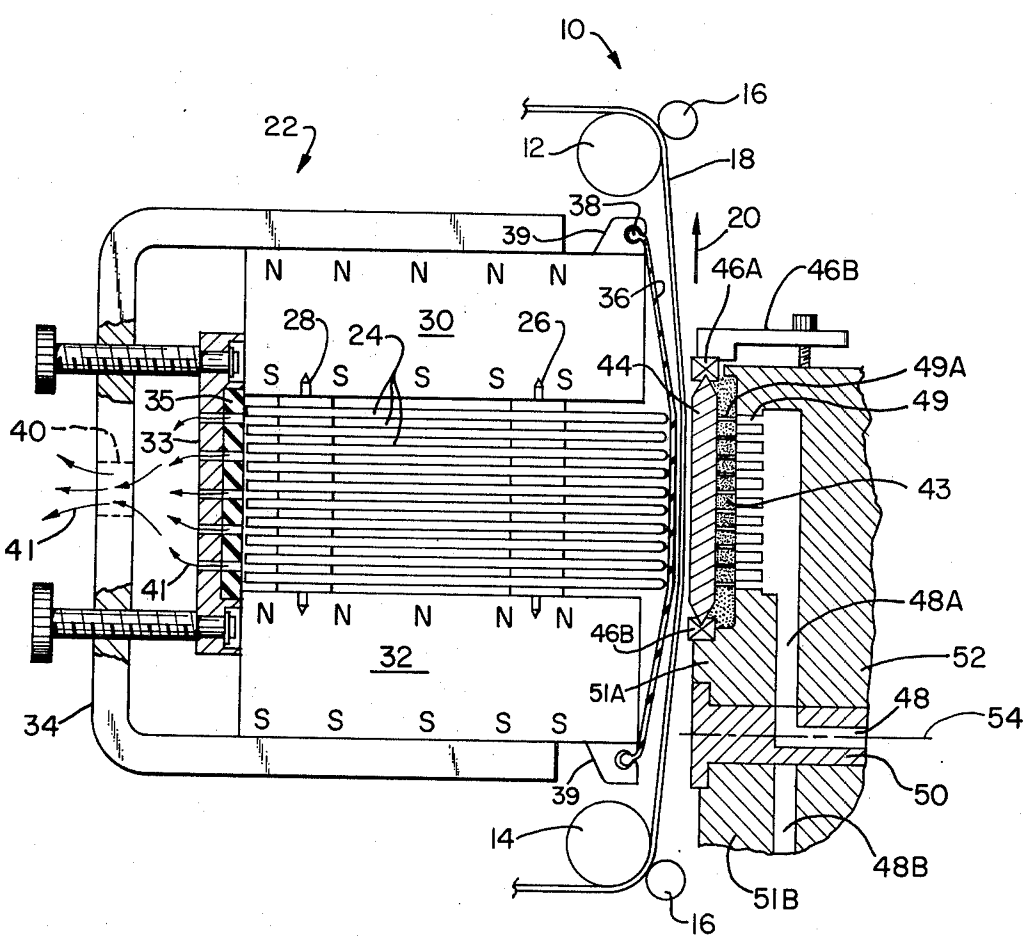
Assistant Examiner—B. T. Rader
Attorney, Agent, or Firm—Charles Hieken; Jerry Cohen

[57] **ABSTRACT**

Representational characters and other images are printed on paper as a matrix of dots or lines produced by pressure between one or more bladed hammers and an inked anvil spanning the paper. Members of an array of parallel elongated blades are selectively activated to hammer at the anvil across a short hammer stroke space. The elongated anvil is arranged orthogonally to the blades and scans along the blade edges parallel to the direction of blade elongation. The blades are preferably transducers of low mass and low thickness and are operable through a short edge-on hammer stroke by the selective application of electrical driving signals thereto. The blade hammering is controlled by electrooptically scanning a selected character of a font of alphanumeric or other representational characters or codes or other image information stored in a read-only memory of the apparatus for local processing or transmission or conventional scanning of subject matter or by signals delivered from electronic processors.

38 Claims, 13 Drawing Figures



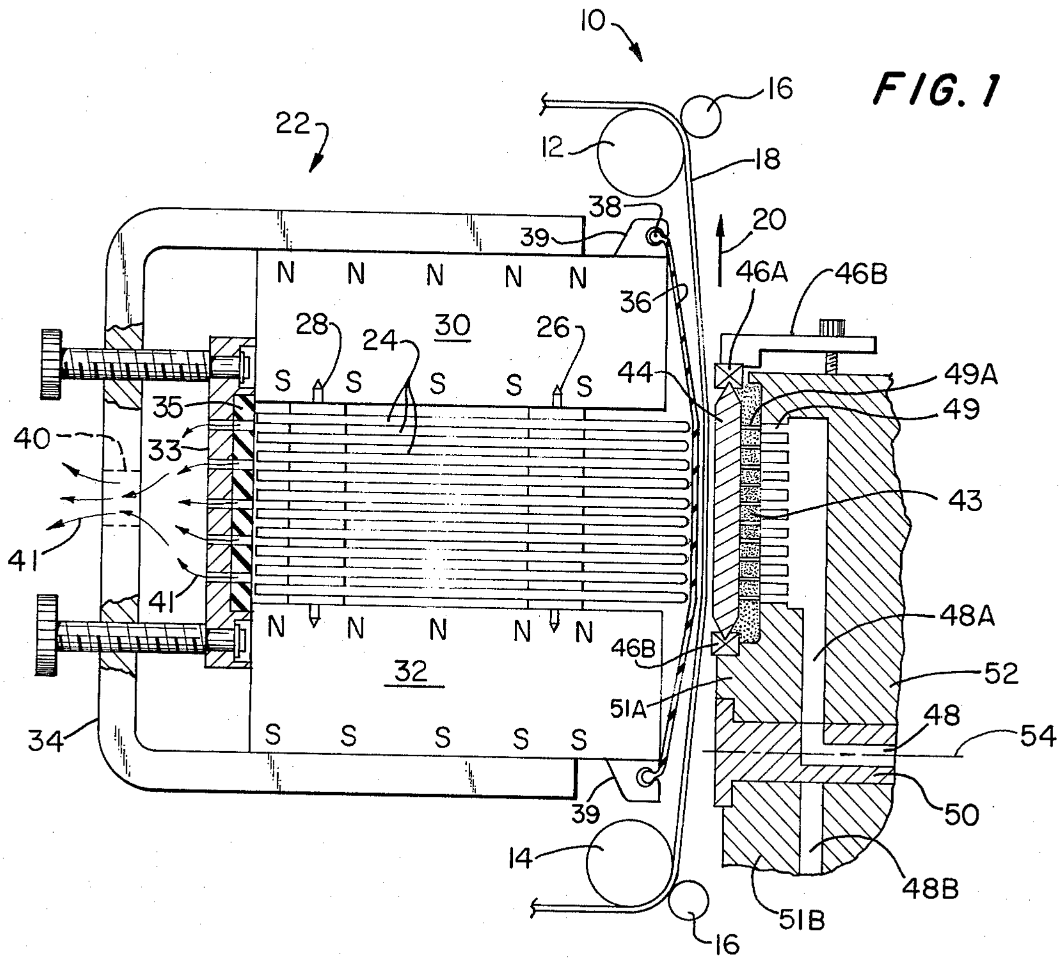


FIG. 1

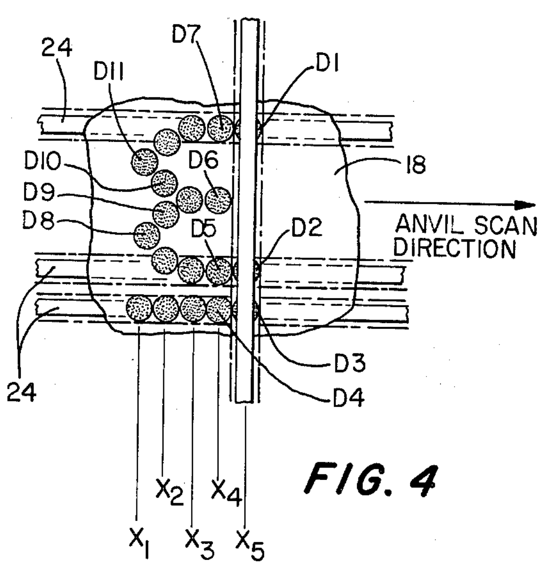


FIG. 4

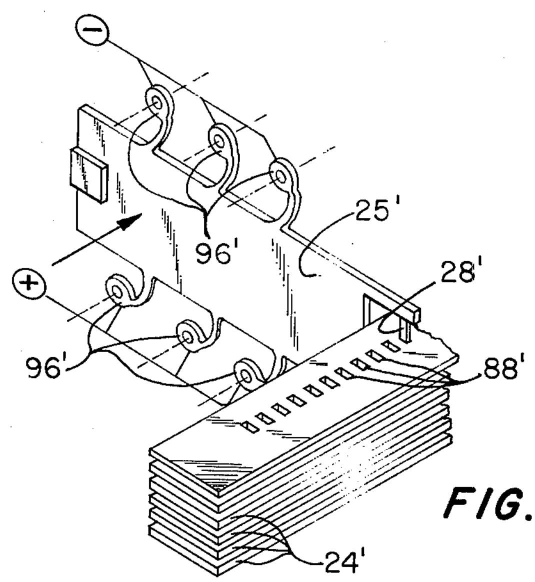


FIG. 10

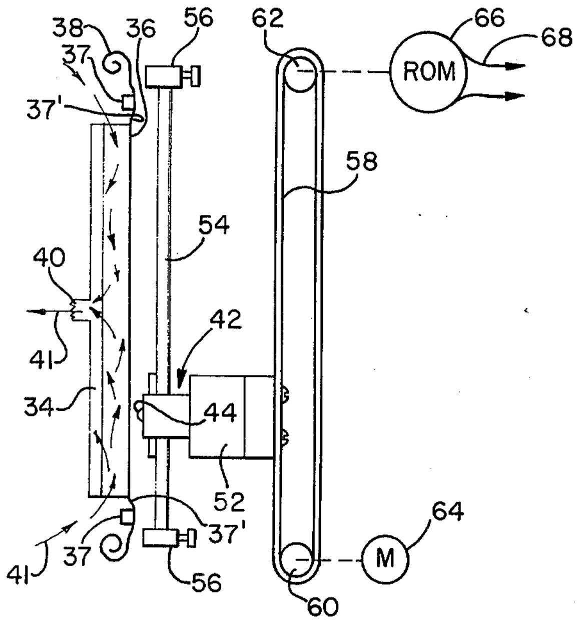


FIG. 2

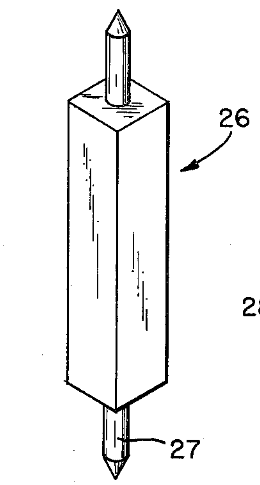


FIG. 6

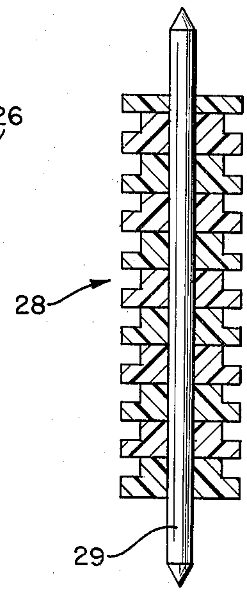


FIG. 7

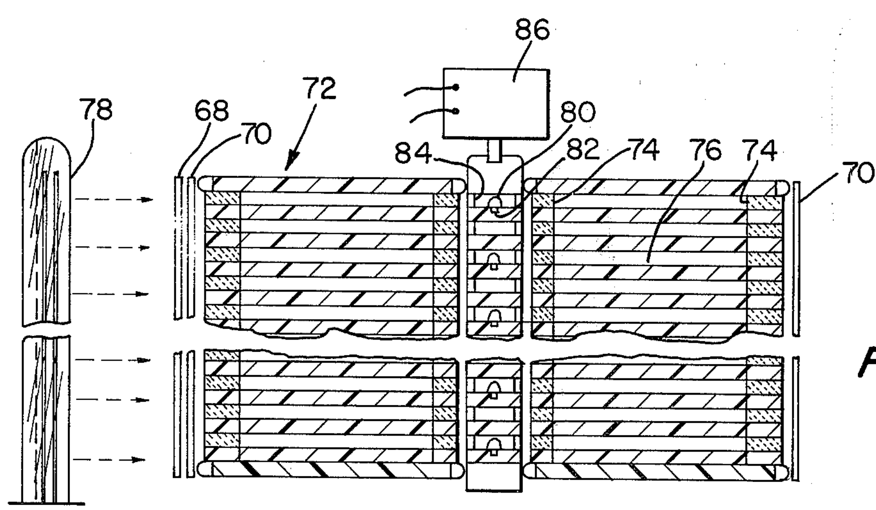


FIG. 3

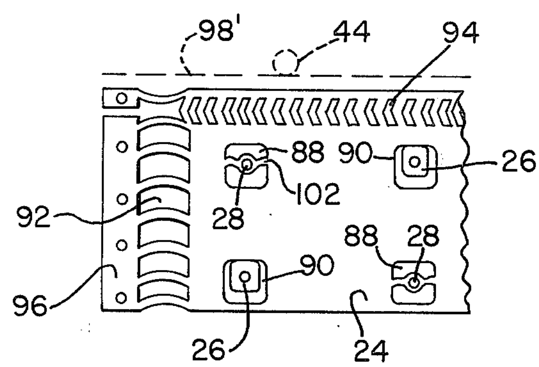
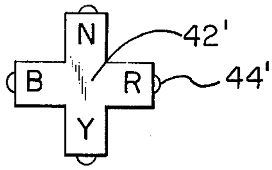


FIG. 5

FIG. 9



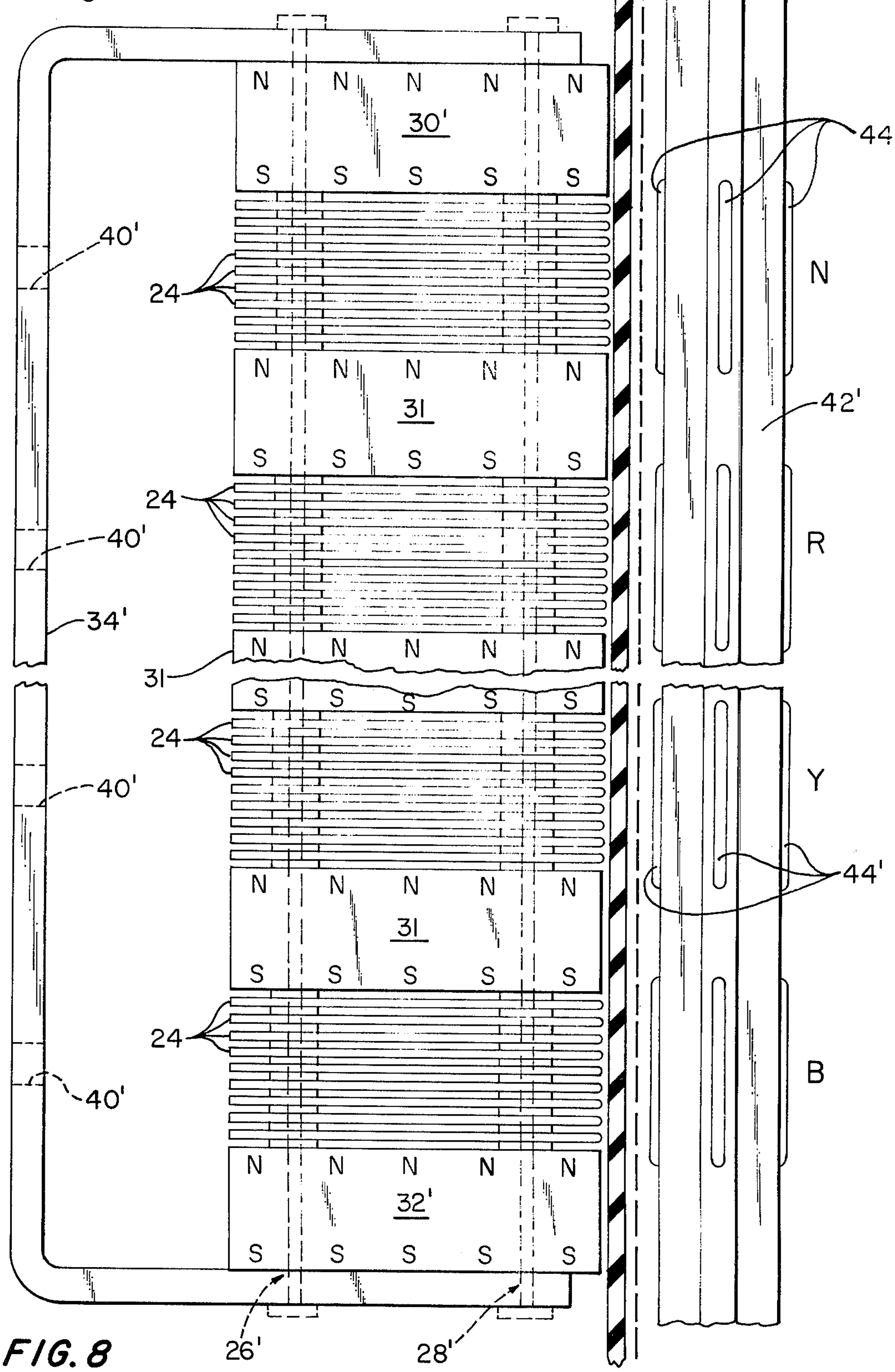


FIG. 8

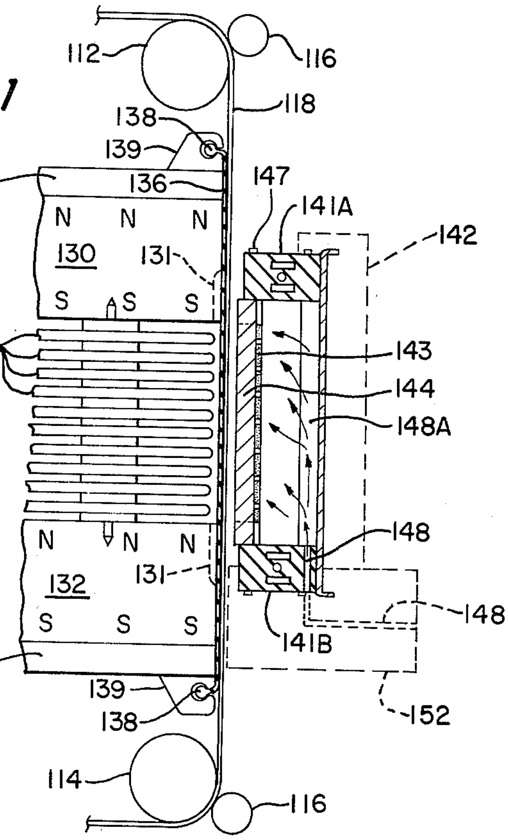


FIG. 11

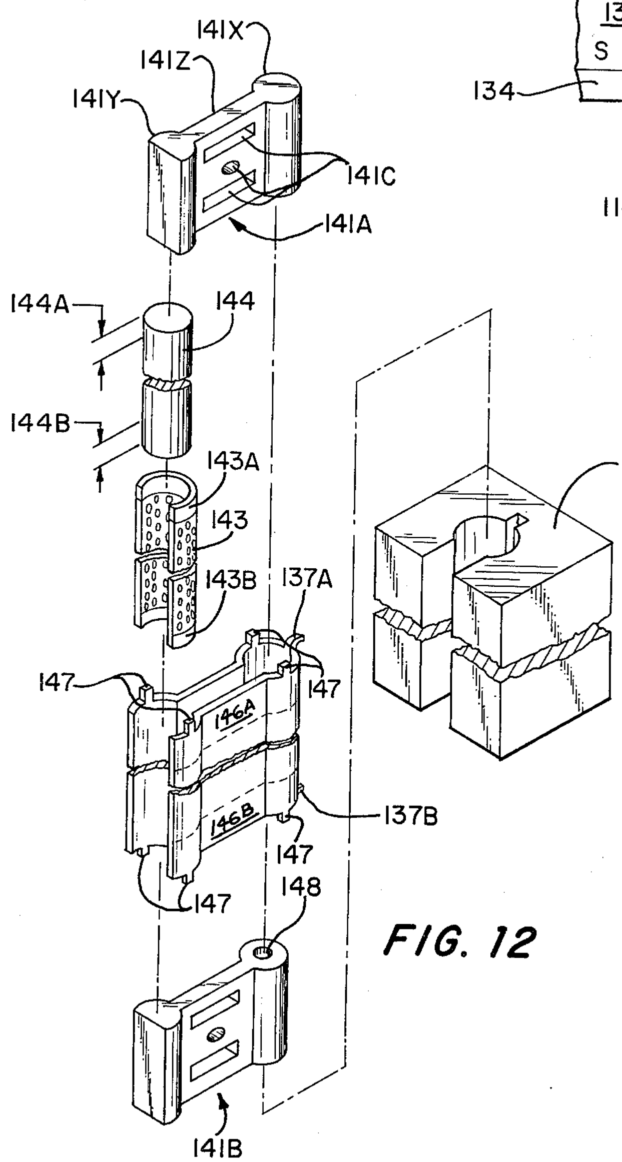


FIG. 12

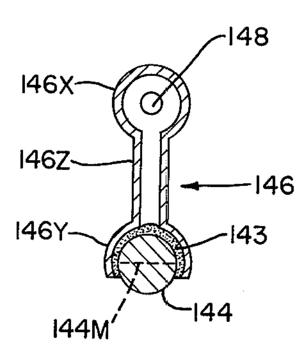


FIG. 13

PROCESS PRINTING

BACKGROUND OF THE INVENTION

The present invention relates to high speed, low inertia printing apparatus. It is a particular feature of this invention that a full variety of high resolution imagery including contours, shading, shapes and colors can be printed preferably by process printing, i.e., nonengraving methods such as photomechanical or photomechano-electric printing in black and white or in any hue produced by superimposed primary colors, at high speeds and with low cost, reliable apparatus.

It is known in the printing arts to produce representational characters, as genuine lines or as line-approximating matrices of spaced dots, on a paper or other substrate using impact or non-impact printing means. Where impact means are used, e.g. in typewriters, an inked ribbon and paper are passed between two coacting impact elements (e.g. key-operated hammers and reaction anvil roller) one of which strikes the back face of the ribbon to force transfer of ink from the ribbon to the front face of the paper.

In U.S. Pat. No. **2,656,240,** one or more vertical plates hammer the paper front with the ribbon passing between the hammer(s) and the paper. A plurality of reaction anvil backing bars are provided behind the paper and are sequentially operable through a cam drive to make desired ones of the anvil backing bars coact one at a time with the hammer to produce a desired array of interconnected dots on the paper. The hammer translates in a scanning direction, and the anvils are arrayed in a direction perpendicular to the scan direction to provide the necessary two degrees of freedom for character generation on the paper.

It is an important object of the invention to provide matrix scan printing apparatus which can simultaneously produce multiple width variable lines or fat to thin dots along one of two orthogonal matrix coordinates.

It is a related and further object of the invention to achieve the preceding object with continuous scanning along the other orthogonal matrix coordinate to afford high speed of printing, reduce inertia problems and simplicity of design.

It is a further object of the invention to print on ordinary paper consistent with one or both of the preceding objects.

It is a further object of the present invention to provide a high speed, low inertia printing head avoiding the use of inked ribbons consistent with one or more of the preceding objects.

It is a further object of the invention to provide low inertia, high speed impact printing apparatus which prints an interconnected dot matrix to form complete lines rather than spaced dot approximations consistent with one or more of the preceding objects.

It is a further object of the invention to provide printing apparatus which produces connected dot matrices as clean, solid letters, alphanumeric characters or other representational characters or patches or blocks or other images consistent with one or more of the preceding objects.

It is a further object of the invention to produce dots of essentially infinitely flexible spacing in a scanning direction and less than **15** mils width and **15** mils spacing in a direction angular to the scanning direction consistent with one or more of the preceding objects.

It is a further object of the invention to handle a large, full spectrum of characters such as variously styled upper and lower case of an alphabet consistent with one or more of the preceding objects.

It is a further object of the invention to provide low cost of construction and operation consistent with one or more of the preceding objects.

It is a further object of the invention to provide an available speed of printing in portable models of over **1,200** words per minute and in heavy models over **60,000** words per minute consistent with one or more of the preceding objects.

It is a further object of the invention to provide apparatus which is quiet or in selected embodiments totally silent in its operation.

It is a further object of the invention to provide a wide flexibility of types of information displayed, easily interchangeable in the apparatus.

It is a further object of the invention to provide a capability of accommodating multi-sheet printout, i.e., use of carbon copies or carbonless base paper, consistent with one or more of the preceding objects.

It is a further object of the invention to accommodate a variety of types of paper, including ordinary typing paper, and widths thereof consistent with one or more of the preceding objects.

It is a further object of the invention to provide multicolor selection and/or mixing print capability consistent with one or more of the preceding objects.

It is a further object of the invention to minimize friction consistent with one or more of the preceding objects.

It is a further object of the invention to minimize wear and to automatically compensate wear consistent with one or more of the preceding objects.

It is a further object of the invention to minimize power needs consistent with one or more of the preceding objects.

SUMMARY OF THE INVENTION

According to the invention, an array of bladed hammer elements and an elongated, inked reaction anvil confront each other across a short space to span a path of paper movement with the anvil in front of the paper and the blades behind the paper. The anvil is translatable across the width of the paper in a scanning direction. The blades are elongated in the scanning direction and the anvil is elongated angularly, preferably orthogonally, to the scanning direction. The blades are selectively operable to make short edge-on hammer strokes towards the anvil, in a direction orthogonal to both the scanning and anvil elongation directions, to press the paper at the one or more dot size intersections of the orthogonally arranged anvil and blade(s). Ink transfers from the anvil to the paper solely at such pressurized dot intersection(s) to selectively produce spaced, superimposed or overlapping adjacent dots which together generate representational characters. The selective blade operation and anvil scanning provide two degrees of freedom for generating printed matter.

The anvil is supported in a low mass anvil housing containing an ink canal leading to the anvil. Means are provided for feeding ink to the side of the anvil away from the paper and the anvil is rotated during its scanning movement. This causes continual transfer of ink to the anvil surface from which it is transferred to the paper at the points of dot impact between the coacting blades and anvil.

The blades are transducers, preferably an array of electromagnetic transducer blades in a magnetic field running parallel to the arraying direction. An electric current is selectively passed through one or more of the blades in a direction parallel to the scan direction to selectively actuate them to move in a direction determined in accordance with the right hand rule to hammer the paper against the anvil. The blades may typically be of **1–15** mils thickness with the separation between adjacent blades typically **1–15** mils to provide high resolution of dot size and placement.

The scanning drive of the anvil housing is integrated with a scanning drive of an electrooptical readout device scanning a selected portion of a font of alphanumeric characters or other representational indicia to be printed. The electrooptical device comprises an array of optical paths replicating the array of blades to provide a simple readout memory control of blade actuation. The control is also infinitely flexible in regard to the spacing of dots along the scanning direction rather than limiting the scan direction spacing of dots to precise invariant intervals. Thus, the apparatus can produce high fidelity of image formation in relation to a given font of representational characters to be printed out by the apparatus.

These and other objects, features and advantages of the invention will become apparent from the following detailed description of the preferred embodiments taken in connection with the accompanying drawing in which

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a section side view of a printing head according to a first embodiment of the invention;

FIG. **2** is a sectioned top view of the printing head;

FIG. **3** is a sectioned side view of an electrooptical readout element of the FIG. **1** embodiment;

FIG. **4** is a diagram of orthogonally arranged blade hammers and an anvil showing the production of standard unit matrix dots produced in operation of the embodiment of FIG. **1**;

FIG. **5** is a partial plan view of one of the blade elements of the FIG. **1** embodiment;

FIG. **6** is an isometric view of one of a number of pin elements used in the blade array of the embodiment of FIG. **1**;

FIG. **7** is a sectioned side view of one of several spring pin elements used in the blade array in the FIG. **1** embodiment; and

FIG. **8** is a side view of a multiple array printing head and multiple anvil combination according to a second embodiment of the invention;

FIG. **9** is a top view of the multiple anvil means of FIG. **8**; and

FIG. **10** is an isometric view of a portion of a printing head according to another embodiment of the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to the drawing and more particularly FIG. **1** thereof, the apparatus of a first embodiment of the invention comprises a printing head for feeding paper or other printable substrate, an array of hammer blades, a reaction anvil and an ink feeder. The printing head **10** comprises an advance roller **12** and a reverse roller **14**, both confronting idler rollers **16** and passing paper or other printable substrate **18** therebetween in a direction of advance indicated by the arrow **20.** Although only one sheet of paper is shown here, it should be understood that the print mechanism is capable of producing up to six or seven high-quality carbon copies or up to **18** or **19** carbonless base copies.

A hammer blade pack **22** comprises an array of thin metal blades **24** held together and spaced from each other by pins **26** and **28** passing therethrough and described in greater detail below. The pins confine the array between a pair of end plates **30** and **32** which also comprise magnets or magnet components establishing a magnetic field going through the blade array in a direction perpendicular to the direction of blade elongation.

The blades **24** are made of springy metal which have low resistivity. They are coated with a self-lubricating dielectric coating. Suitable blade materials comprise phosphor-bronze, molybdenum, copper, beryllium-copper, boron-aluminumcopper-tin alloy. A preferred coating material is Teflon. The blades may be **3–15** and preferably **5–10** mils thick, including coatings on each of their flat surfaces of about **0.1–1.0** mils thickness with the separation therebetween typically from **1** to **10** mils. It is preferred to avoid entirely or minimize intervening fixed stator or bearing elements between blades and to have the blades spaced from each other preferably by **2** to **8** mils, the exact figure depending on the spreading characteristics of the ink and paper used. A lowermost one of the arrayed blades **24** is actuatable by a mechanism separate from the actuator of other blades to print underlines, preferably simultaneously with the underlined letter.

Referring now to FIGS. **1** and **2** together, a wrap-around plate **34** is placed across the back of the blade array and a flexible curtain **36** is placed across the front of the blade array to define a dust cover and a cooling passage admitting ambient air or other gas coolant at its sides. Plate **34** mounts a perforated plate **33,** with elastomeric energy absorbing facing **35** [e.g. Cabot Corporations E-A-R or other PVC solid]. The curtain prevents dust from getting into the striker system. The inner surface bears lubricant which protects the blade and other edges from wear. It aids in the proper formation of image elements. It reduces impact noise. To replace a worn curtain, a new length of same may be drawn from a storage reel. The curtain has rod rest cushions **37** at its ends to store the anvil rod described below, and fibrous surface sections **37'** to wipe the rod as it passes.

The curtain is secured by a bead **38** around its edge and the wrap-around plate **34** has a port **40** therein which serves as an exit for coolant. Continuous circulation of air through the blade array is provided as indicated by arrows **41.** The circulation may be convective or forced.

The curtain is coated with a lubricant, such as sodium metasilicate or graphite, in a thickness of **0.1** to **0.9** mils on its fabric or inner surface which confronts the blades to present fresh lubricant to the blades from time to time or as needed. The lubricated curtain protects the blades from damage or wear and prevents paper scratching or cutting by the blades. The curtain also aids in the proper formation of dots at the pressure impact intersections of orthogonally arranged anvil blade(s). Preferably the curtain is made of stretch fabric (suppored or non-supported) cross-linked polyurethane, neoprene, or polyester film. Fabric when used is impregnated with an elastomer such as neoprene, or plastic types. The curtain has a thickness of **0.5** to **5.0** mils. Different fabrics (e.g., one or two-way stretch fabric for a "supported" type curtain) or thickness of curtain will produce various aesthetic printing variations.

The blades have a small, but essentially inevitable, degree of up and down vibration in the course of operation which tends to facilitate coolant flow and to induce transport of the curtain's lubricant along the blade surfaces.

An anvil assembly **42** confronts the array of blades **24** and comprises an anvil roller rod element **44** which is elongated in a direction perpendicular to the scan direction whereas the blades **24** are elongated parallel to the scanning direction. The anvil rod is mounted between end bearings **46**A and **46**C. Bearing **46**A is mounted on a spring **46**B to bear down on the rod end easily. The rod is rotated easily through frictional engagement with the paper as the anvil head assembly **42** is displaced across the paper in the scanning direction which can be left-to-right, right-to-left or both.

An ink carrying canal **48** passes through a feeding pin **50** carried in a carriage **52.** Carriage **52** is movable along a rail **54** extending in the scan direction to translate anvil **44** along the width of paper **18.** A pump or pressure source feeds ink into **48.** The canal **48** continues into a selected arm extension **51**A of the carriage structure which preferably has two or more of such star-form extensions e.g. **51**A, **51**B to allow for color change, inked line or dot width change, ink feed rate change or mere replacement of worn rods without disassembly. The canal extensions are selectively connectable to or blocked from the canal portion of the feeder pin by rotation of the arms and/or rotation of the feeder pin constituting a selector valve action. The arms must be rotated in any case for positioning opposite keyblades or removing from such position. The canal extension on each arm terminates in plural exit ports **49** arrayed opposite anvil **44.** The ports **49** have capillary extensions **49**A.

The anvil assembly **42** has an absorbent packing **43** surrounding all of anvil **44** except the portion of the anvil confronting paper **18** at any given time. The packing is preferably made of microporous sponge or chopped synthetic plastic fiber. The packing prevents too much ink from being supplied to the rod and seeping around it, and at the same time assures minimal friction and thorough ink distribution. It is shaped so as to keep the rod from falling out, more particularly at solid end portions. For further positional stability, magnetic material may be used in the anvil rod and anvil bearings so they will mutually attract and thereby suppress wobbling. A bearing, as of stainless steel or boron carbide, or literally the packing's solid extremity, is provided at each end. The anvil is vibrationally grounded through the cursor and track to the machine chassis so that it provides something firm against which the paper is pressed by the leading edge of an enabled keyblade. The anvil rod is rigid yet thin enough to permit seeing enough of the last symbol printed to identify it.

The rod will undergo a distinct change of shape as it is worn in at blade impact sites and diminishes in diameter to form a wavy rod surface. As the anvil-rod wave pattern develops, ink is absorbed by the packing, causing it to expand and fill the troughs on the rod. Without this feature, the ink would start to leak around the rod when it became worn and so lose its binary transference properties described below. In other words, the surface electrical forces of the rod and ink would become relatively too weak to prevent the film from transferring too easily to the paper, whereupon degrading imagery would occur.

Referring now to FIG. **2** alone, the rail **54** is adjustable by micrometer lead screws **56** to precisely set anvil to paper spacing to accommodate variable paper thicknesses and varying numbers of sheets. The carriage is mounted on a timing belt **54** which is driven over pulleys **60** and **62.** Pulley **60** is driven by a motor **64** via a clutch or ratchet geared means (not shown) and a pulley **62** is connected to the scanning wheel element of a read-only memory **66** for coactive scanning by the carriage **52** and the read-only memory **66.** A font **68** surrounds the cylindrical element of the read-only memory **66** and the font can be changed by circumferentially pulling on font element **68.** The carriage **52** scans the anvil **44** along the width of the paper **18** and drives the ratchet geared cylinder.

The carriage weighs only a few ounces, a fact which not only permits extremely rapid advancement but also virtually eliminates the time and bounce problem associated with its rapid return to starting margin. Either a springloaded or powered return, both well known in the technology, is applicable here, but for a reduction of parts, the powered return is preferred. A timing belt or band transmits motion simultaneously to the carriage and scanning cylinder of the ROM (Read-Only-Memory, which generates character signals) so as to assure coactive symbol generation and inking. The motor is preferably a stepping motor with counter, but other well known means of driving the carriage and memory, such as servos or conventional combinations of a constant speed motor with an appropriate clutch, may be used. There are at least several species of hydraulic rotary or linear-ram type motors which also would suffice.

Referring now to FIG. **3** the read-only memory is shown in greater detail as comprising the above mentioned font **68** containing therein slits **69** surrounding a scanning cylinder **70** which in turn surrounds a stack **72** of rings **74** interleaved with baffles **76** to define a number of levels of discrete optical paths.

The optical rings serve to separate the baffles and transmit light on its way to the photoreceptors. In the embodiment employing gas-discharge lamps, these rings should be coated with clear tin oxide which in turn is grounded so as to prevent RF from reaching the sensors. The rings may be made of plastic. The inner surface of the outside optical ring of the light-trap is formed into curved sections so as to provide focusing of a reasonable portion of the light to the photoreceptor lensing. For each character position, the scan cylinder is perforated with a row of scan holes. In close physical relationship to the transparent elements of the font, each scan hole acts as a light shutter, so to speak, when it moves by one or more such transparent portions passing light.

The scanning cylinder **70** and font **68** are relatively movable coactively with reaction anvil scanning along the paper. Preferably the mask is stationary and slits or aligned holes in the cylinder associated with enabled light sources which constitute virtual light sources scan letter width. In lieu of an array of light sources such as neon lights 78, flat electroluminescent light emitting elements may be disposed outside the font 68. When a clear light path is provided by font 68 and scanning cylinder 70, the light from the source passes inwardly through the optical paths to one or more of the sensors 82 which are provided with hemispherical dome or fish eye lenses 80. Only a first alternate set of the stacked radial light paths is aligned with the detectors 82; a relay 86 can be activated to move the detectors 82 into the second alternate set of light paths. The two sets of positions for detector 82 may accommodate upper and lower case of the same letter using a shift key to activate the relay 86. The detectors 82 are, per se, conventional photoelectric elements such as light sensitive diodes or transistors.

A typists' keys may be activated singly, or in simultaneous multiples for overlapping letters, to light up a lamp or lamps 78 and start motor 64. Motor 64 drives the anvil 44 and scanning cylinder 70 as described above. Movement of scanning cylinder 70 passes a slit 69, or a line of holes, thereof in front of the lamp to provide a moving virtual light source scanning transparent sections of the letter (font 68 section) corresponding to the struck key. The slits 69 are uniformly spaced in cylinder 70 at the same intervals as spacing of lamps 78.

The light from this source passes to a photodetector 82 to enable a blade 24 at any given height section of the height array thereof only so long as the relatively scanned virtual light source and a font "window" coincide circumferentially at such height section.

The number of blades in an array and corresponding photodetectors in an array is preferably nine for each array, but separately actuated underline and/or overline blades may be added to increase the blade total to eleven per array. The blades of basic group of nine (and the number may be substantially more or less for non-alphanumeric employments of the invention), can be activated or inactivated in any selection or combination thereof.

Referring now to FIG. 4, the generation of characters by the above described apparatus is illustrated. Although the following discussion is in terms of spaced dots with an infinitely flexible horizontal spacing, it will be understood that a true continuous horizontal line or lines can be produced by holding a blade or blades enabled while displacing the anvil therealong to produce a horizontally stretched dot(s) or continuous sequence thereof; i.e. a line(s). A small section of paper 18 is shown, and three blades 24 interact with the anvil rod 44 to produce a number of dots indicated as D1, D2, D3, et seq., interconnected together as an underlined letter E. At the moment in time shown in the drawing, the anvil 44 is producing three dots D1, D2, D3 through coaction with three blades 24 activated by enabling their corresponding photodetectors in the read-only memory or enabling the upper two of the three blades through such means and separately enabling the lowest blade via a separate underline key and signal translator. The chain line tolerance limits around each of the solid elements 24 and 44 indicates the allowance which must be made for misalignment, ink spreading and lateral vibration of the elements involved as well as the wiping time of the anvil 44 while in pressure relation with one or more blades 24. At the instant in time shown in the drawing, dots D1, D2 and D3 are being produced at a scanning location X5. At a previous instant, dots D4-D7 were produced at scanning location X4 by the same blade 24 plus an additional blade and some instants earlier only dots D8–D11 were produced at scanning location X1 by several blades. The interval between adjacent scan locations X1, X2, X3, X4, X5 corresponds to the timing of successive blade hammer strokes and can be made fixed or variable. The rod size may be changed to effect different element widths. The vertical contact portion of the anvil-rod is the portion of the cylinder which would receive ink transfer pressure sufficient to print an element of imagery in the course of a minimally timed yet complete keyblade cycle, it being understood that the rod will begin to roll immediately and will therefore in the course of any longer cycle extend the element into a line as the cursor moves across the image area. For different papers, a full gradient of contact pressures is provided through adjusting micrometers 56.

The image elements of the enlarged E will integrate when produced on the scale associated with the printing means of the invention. Other matrix machines are limited by memory or printing means or both to rigid letters which are generally not integrated well enough to sustain reading for more than a few pages without suffering eye fatigue. In contrast, both the memory and printing means of this invention support the rapid and sustained scanning of the text by the reader in a manner to which he has been conditioned over the years by reading text produced by traditional printing means. The size of the image element may be one-hundredth of an inch in the vertical. Hence, with the nine elements specified, although more elements may be added both in memory and the printing means to enrich the curvilinear repertory of the symbol forms, the normal letter height will be about one tenth of an inch, even less with smaller elements.

Most matrix memories and/or printing means produce dots only, and these in fixed positions in the horizontal dimension of the symbols produced. In contrast, the dot is only a special case of the line-producing capacity of the present invention. Just as important to the structural verisimilitude of well known alpha-numeric morphology, the placement of such elements of imagery as are produced by the present invention is not constrained to a fixed number of positions for any and all characters. Rather, the form of the letter, not the limitations of the invention, determines where its elements of imagery are placed in the dimension of the scan. In this regard, the present invention is genuinely similar to image-generating methods well known in television technology, except that a major difference consists of the ability of the machine to produce several closely spaced parallel scans at one time, so closely associated, in fact, that genuine overlapping supports integration in the vertical dimension.

Referring now to FIGS. 5, 6 and 7 component portions of the blade pack 22 are shown in greater detail. Each blade 24 comprises a number of holes 88 and 90 along its length, holes 92 along its ends and holes 94 along its hammering edge 98. The holes 90 define the limits of movement of the blade in the hammering direction.

Side edges 96 of the blade provide flexible terminals for application of an electric field across the blade length and provide support points for blade ends which allow movement. The holes 94 along the hammering edge 98 of the blade give a spring character to intervening zig-zag strips 100 to prevent destruction of the long hammering edge in case of mixtake in setting blade driving force or spacing from the reaction anvil. This distributed edge spring assures that regardless of relative displacement position of anvil and blade edges the pressure applied therebetween will be the same and safely below the paper penetration theshold.

Spring strips 102 formed integrally in the blades interconnect the blade with the vibrationally grounded stack of washers 28 via washers with collars to allow for the necessary forward and return movements of the blades. The washers are mounted on pins 29 anchored in the upper and lower plates 30 and 32 of print head 10 (FIG. 1). The blades' stop pin holes 90 are arranged in alternation with the washer stack holes 88 and distributed across the full length and width of the blades, preferably with two lines of 2–3 each per inch of length, to assure control over the full lengths thereof. Each blade has a dielectric coating of 0.1–1.0 mil thickness on its surface.

A typical set of design parameters of the print head is now set forth. The blades are phosphor-bronze strips 0.5 inch wide, 12 inches long and 0.005 inches thick. The magnetic field in the gap between plates 30 and 32 is 5000 gauss, or 0.5 webers per square meter. Under these conditions translation time for a blade hammer strike is about 1 millisecond and blade return time is about one millisecond for a stroke distance of 10 mils. Nine blades are used with a separation of 7 mils between adjacent blades. If on the average half the blades are operated at any given moment, power dissipation is about 40 watts. Attracting forces between blades are less than 10% of blade translating force in the hammering direction and losses due to cross-talk between adjacent blades [mutual inductance coupling during electric field transients in the respective blades] is 17% or less.

The blades may be of virtually any length since force to mass ratio will remain the same for purposes of the above calculations provided that current is maintained at the same level. The blades preferably have an areal aspect ratio (length to width) of at least 5*x*.

The collar supporting pins 29 and stop pin 26 are made of nonmagnetic materials and the washers 28 are made of nonmagnetic, dielectric material. Pin 29 is dielectrically isolated from the blades by the washers to prevent short circuits between blades. Stop pins 26 are made of precisely formed low bounce material such as Teflon and serve to transfer vibrational energy out of a blade pack system as well as defining forward hammering and return limits for the blades.

The various spring defining holes of the blade body can be made by electrolytic boring to form all such holes simultaneously and to manufacture multiple blades simultaneously.

The low ohmic character of the blades assures that heat generated in them will not be too much for the cooling air stream to carry away and reduces the likelihood of high, distortion-inducing levels of electric current being drawn. The blades are preferably made of nonmagnetic materials. The thinness of the blades' dielectric coatings is a minimal barrier to heat transfer.

Used lubricant after passing along the blades can settle on the wraparound plate or energy absorbing barrier (FIG. 1) and this can be enhanced by flocking the surfaces of such plate or barrier. Additional sound absorbing material can be added to such barrier and plate with clearances for blade movement and cooling air flow. The coolest air plays over the flexible electric connections at the blade ends (FIG. 5) and then passes to the blade centers and finally the two end-to-center flows meet and, together, exit out of the blade pack apparatus through the exit part(s) described above.

FIG. 8 shows a side view of a second embodiment of the invention comprising a printing head 10'and multiple arrays of blades 24 between upper and lower plates 30' and 32' and midplates 31. A wraparound plate 34', with multiple air exit orifices 40' therein, and a curtain 36' define a cooling air flow chamber and protect the blades and paper as in the FIG. 1 embodiment. Stop pins 26' and washer stacks 28' are common to the several arrays. A modified anvil housing 42' is made of rotatable multiple leg form to support a height array of several height aligned sets elongated anvils 44' opposite each of the several blade arrays.

Some of the blade packs and anvils in the array thereof may provide a process printing without ink capability and/or without displacing the blade edges of such packs by setting the anvil rod at ground potential and selectively setting driving potentials on the blades of such packs. Electrolytic or electrostatic papers may be used as the printing substrate.

The movement of blades can assure contact where necessary and be used to produce an enhancement of the well known pinching effect to print such papers. Alternatively, the blades of such packs can be locked in place, e.g., by adjusting the blade stop pin configuration and/or position; and delivering signals to the individual blades. As a further alternative, such packs can be made of multiple spaced metal layers separated by dielectric layers in a block construction. In such embodiment, the ink feed means and curtain would be eliminated.

Referring now to FIG. 9, the housing 44' of FIG. 8 is shown in top view, and the legs are marked with the letters N, B, Y, R to indicate that different color inks are fed to each of several anvils 44' of a given height aligned set.

The FIG. 8 embodiment allows simultaneous production of a whole page. Typewriting a letter size page with normal margins and typical business document character spacings, heights and widths and margins could be produced in about 1.0 seconds. Alternatively, smaller increments of a page greater than a line can be produced.

The multiple leg anvil housing shown in FIGS. 8–9 may be used to provide multi-color capability in repeated scans over the same paper area or by sequential attack of a given paper array be sequential reactionanvils of the height array of anvils or anvil sets. Alternatively, the multiple anvils may be used monochromatically for fast replacement of worn anvils. One or more of these capabilities may also be incorporated in the FIG. 1 embodiment as well as the FIG. 8 embodiment.

Several rotatable anvils or anvil sets may be mounted to separate carriages for accurate displacement and position control. Normally, color would be distributed in multiple-set machines as shown in FIG. 8; but alternatively the colors can be changed as indicated here by anvil-assembly rotation by well known turning means. The FIG. 1 embodiment can employ a multiple anvil set as shown in FIG. 9 for color control, line width control or quick replacement capacity.

The useable life of the typical rod is enhanced by the lubricity of the ink and is further enhanced so as to last for many billions of rotations due to the absorbent packing's ability to follow the contours of wear which in time develop on the rod's surface. Such wear may be equalized by vertical adjustment of track **54** or by imposing a constant very slight bow or slant thereon. Although the geometry, dynamics and wear patterns of the rod are quite different from that of the sphere of a ballpoint pen, the same or similar ink-attractive materials employed in such pens would be appropriate for rod fabrication. Alternate materials, such as tungsten carbide or born carbide, may be used as rod materials or as rod surface coatings to provide wear resistance.

FIG. **10** shows another embodiment of the print head in which the electromechanical bladed hammer transducers are subdivided into separate hammer and transducer portions. Each of hammer blades **24'** is connected to one or more driving transducers **25'** via a holding pin **28'**. Each hammer blade **24'** has holes **88'** therein allowing stroking distance for hammer stroking distance of pins connected to other hammer blades. The transducers are arrayed in a magnetic field H and have spring form edge terminals **96'**. At least two spaced transducers **25'** are connected to each blade **24'**.

In the FIG. **8** embodiment as in the FIG. **1** embodiment, the elongated edges of the blades of each array are essentially stacked, parallel and in a common plane. The curtain across the blade edges recedes back in the FIG. **1** above and below the edge stack to allow anvil bearing clearance but stays flat in FIG. **10.**

FIGS. **11–13** show another embodiment of blade pack and ink feeding and reaction anvil apparatus allowing a flat curtain arrangement and also affording compensation of anvil wear and ease and economy of manufacture. Referring to FIG. **11**, an array of blades **124** is confined between magnet poles **130, 132.** A curtain **136,** with end beads **138** in retainer **139,** is held across the leading edges of the blades **124.** A paper **118** is fed between upper rollers **12, 116** and lower rollers (not shown) to pass between the curtain and an anvil **144** arranged orthogonally to the direction of elongation of the leading edges of blades **124.**

The anvil **144** is mounted on a carriage **152** having an inch passage **148** therein and also having a housing for anvil **144.**

The housing (FIGS. **11–13**) comprises a long metal plate **146** cut and bent to the form shown to provide (FIG. **13**) a circular section ink channel **146X**, a crescent section rod holder **146Y** and a thin interconnecting passage **146Z**. The bent plate has a natural spring tendency and it is mounted in a socket **142** to urge the legs of the bent plate compressively towards each other. Plate **146** has bendable key tabs to lock itself into socket **142.**

An expansible packing **143** (FIGS. **12–13**) of crescent form, and preferably perforated, is snugly engaged in holder **146Y** and has solid ends **143A** and **143B** to avoid leakage of ink therethrough. The crescent holder and packing extend around more than a full half circle of roller **144,** i.e., beyond the midline **144M** (diameter) thereof to assure stable bearing retention.

Compressable, perforated, foam end plugs **141A** and **141B** are provided at top and bottom of **146** and housed at sections **146A**, **146B** thereof to define roof and floor of the ink flow region and hold packing **143** and rod **144** against endward displacement. Tabs **147** may be bent in to lock in the end plugs. Plug **141A** has a section **141X** fitting into channel **146X**, a section **141Y** fitting **146Y** and a section **141Z** fitting **146Z** and the lower plug has similar sections and may have an ink flow passage **148** punched therethrough (alternatively, ink flow passage **148** could run radially through the back of **146X**).

Features of FIGS. **11–13** and of the FIG. **1** and FIG. **8** embodiments may be interchanged. FIG. **11** also shows relief grooves **131** to equalize the effect of air pressure across curtain **136** affecting the endmost blades oth the array with that of the intermediate blades, an expedient utilizable in FIG. **1** and FIG. **8** as well.

The rod wiping curtain portion **37'** mentioned in connection with FIG. **2** is particularly useful in connection with the FIG. **11–13** anvil support arrangement to avoid ink smears due to ink collection at the edges of the crescent packing. The rod mask **37** is useful for all embodiments to limit curing to a hard film by wet ink films on the roller during long periods of idleness thereof.

Another process printing embodiment of the invention comprises the elimination of ink feeding means and use of carbonless base, impact sensitive printing papers.

Carbon paper and/or carbon or dye transfer ribbon or film may be utilized in the method and apparatus of one or more of the above described embodiments.

To improve flux geometry through the key blade stack, in any of the foregoing embodiments, a measured and carefully limited amount of magnetic material on the order of **10** w/o may be included in the spring alloy of which the blades are fabricated. Since even this small amount would cause the blades to be pulled towards the magnetic pltes closer to them and hence out of their desired functional planes, this distortion can easily be compensated by fabricating the washers over a gradient of thicknesses. This means that each keyblade would be associated with a set of washers of a thickness sufficient to compensate for the vertical deflection of its set of blades.

There has now been described, in several embodiments, apparatus and techniques to produce clean, solid letters; print both cases equally well; afford a full spectrum of character sets and a cost per character set of only pennies; provide speeds independent of font size; do tabulations and flyback in milliseconds, which affords up to **1200** words per minute or more in portable models and up to **60,000** words per minute in heavier models; be barely audible in its operation; go with any keyboard or display (i.e., be universally applicable); do graphics or alphanumerics and in full color, if so desired; handle all substrate widths and fanfold, roll or separate sheets and take paper and mats used in typing or printing and clear carbons up to half dozen; avoid ribbons; avoid upkeep problems, be compact and easy to carry; use low-cost components throughout; and permit also multi-speed motor operation, coactive underlining and instant memory programming.

Such apparatus and techniques may be employed in such systems as time-sharing data processors; plans coordinating systems; interactive systems, home or business; medical monitoring and analysis; dynamic design systems; universal message service; econometric informationn and graphs; status reporting and updating; archives and records search and retrieval; news and advertising services; customer service systems; centralized stenographic services; accounting and control systems; shipping and reservation systems; weather maps and line drawings; identification systems; book and magazine broadcasting; and one-side or two-side duplication.

The following principles are believed to be applicable to explain the mechanism underlying operation of the invention and its contrasts to known printers, such as typewriters.

Ink transfers from a typewriter ribbon only where it is pressed by the metal of the typeface against the paper. Merely bringing the ribbon into direct contact with the paper will not by itself cause ink transfer; otherwise, the centers of each closed letter, such as, the letter "o" would be filled in. The reason for this either-or behavior on the part of the ink is that transfer occurs only where the pressure exerted during printing is high enough to force ink from the ribbon onto the paper. This may be referred to as binary ink transfer, which simply means that a distinct pressure threshold must be exceeded before the ink will genuinely dissociate from the carrier, such as, cloth ribbons, and go over to the paper. A modern carbon ribbon, which is a strip of polyester film bearing a thin layer or film of ink, behaves in much the same manner, except that transfer is even more highly binary here than with a cloth ribbon. Carbon paper works in much the same way.

That the principle of binary ink transfer is not confined to complex systems incorporating a cloth or plastic carrier, as in a typewriter, may be verified by performing the followig simple experiment. First, hold a ballpoint pen at a low angle to a piece of paper on a normal writing surface and push the pen forward. This assures that the ball is loaded, meaning that a thin film of ink now covers most of the exposed portion of the ball. To prove that this is so, hold the pen vertically and bring it directly down onto the paper. This, of course, produces a dot. If while producing this dot one does not roll the ball, bring the pen down again, and see that the dot is lighter or not inked at all. In effect, the ball is loaded with ink and then unloaded by pressure-transferring the ink on its surface onto the paper. It requires substantial pressure to transfer the thin film of ink onto the paper and this may be verified by performing the second part of this experiment.

Load the ball as before, pick up a clean piece of paper and hold it suspended. Now bring the loaded ball into contact with the paper and see that the pen leaves no mark on the paper whatsoever. To be sure gravity is not causing this effect, put edge of paper an inch or two beyond edge of desk and raise or lower pen strictly in the vertical. Repeat this part of the procedure until thoroughly convinced that genuine contact of ball with paper is mad. The fact that it is quite difficult to make any sort of mark on the suspended paper, even by jabbing the pen at it, is not due to a sudden disappearance of ink in the pen. The ink is present but by not having something firm behind the paper against which can bring sufficient pressure can bear on the system, the ink will adhere to the ball much more strongly than to the surface of the paper and, therefore, not undergo the anticipated transference. That the film of ink will transfer quite easily with sufficent pressure, without the ball actually rolling, as was made clear by the first part of the experiment, and yet not do so by merely contacting the surface of the suspended paper basically means that the ball-point pen represents yet another inherently binary ink transfer system. No cloth or plastic ribbon is involved. The ink carrier is the ball itself. The peculiar tenacity with which the ink clings to the ball is primarily due to the fact that the ink is in the form of a very thin film.

This principle of binary ink transfer is utilized by the printing means of the invention. Rather than incorporate a row of balls, each of which would correspond to a blade behind the substrate, the balls may be thought of as fused into a simple cylindrical roller rod against which the blades can effect binary transferences of the ink onto the paper. These transferences of visible matter occur in timed sequences corresponding to the sequences of signals delivered from the readonly memory. When two or more blades are active at the same time, as would be the case while printing the top, middle and bottom horizontals of the letter E, the ink film on the rod will be forcibly transferred onto the paper only where sufficient pressure is brought to bear against the rod by the active blades. In the course of printing these three lines coactively, pressures elsewhere along the vertically exposed portion of the roller will be too weak to bring about ink transfer, a condition analogous to that illustrated by the ball-point pen experiment outlined above, more particularly wherein ink transfer was found to be totally absent even though the fully ink-loaded ball of the pen was brought into direct contact with the suspended piece of paper.

The ink acts as a constantly refreshed agent of lubrication for the anvil roller to minimize machine wear and assure low turning force requirements for rotating the roller whenever one or more blades force the paper against it. By virtue of this rotation the small roller is kept properly inked circumferentially as it is moved laterally across the image area of the machine.

For several employments, the reproductional signal (e.g., font) may be sampled at the intervals rather than continuously as the image area(s) are scanned to lighten the printed image. Modulation may be thus effected by line-width variation of sampled or unsampled lines in the resultant verticals. Light gray may be registered with minimally thin vertical lines with white-space left between them. Using a rule of thumb of one quarter the rod diameter the rod diameter as minimum line width, a twelve-mil rod would deliver a three-mil wide element of imagery. From this minimum through the various shades of gray to black, a gamut of densities will result by progressively widening the contact time. Alternatively, holding elements individually constant and minimal in width, the electrical blade enabling signals may be frequency modulated to effect essentially the same modulation, particularly for monochromatic material in units that would avoid the need for auxiliary equipment required in pulse width modulation.

From this repertory, all shapes, forms and shading can be delivered to the paper as a high element density formatting of the original. Since the invention affords to yield one hundred-line-per-inch resolution in the x-axis [although as few as half that number would do for most representational employments] and the same number in the other axis, one million code positions are contained in an area ten by ten inches. Further, pulse tailoring in accord with transitional information embedded in the signal [e.g. excessive darkness] and encountered in the scanning may be employed to deliver such further information to the paper as skew-compensted image elements. In the absence of compensation such image elements sould be centered symmetrically (zero skew) along any given y-axis of the code format.

Vertical transition material can be applied by proportionally quantizing sequent pulses to produce a high degree of fidelity to the original subject matter, particularly as to edge detail and line and contour definition.

Apparatus and codes for modulation, compensation and mixing and various electrical signal translation functions, as described above, are well known, per se, and are not illustrated here to avoid obscuring this description of the invention.

Full-color signals can control the printing of red, yellow and blue image elements in the same format in which monochromatic matter is printed. Adjacency of as well as literal mixing of the elements of imagery can be secured at code level, the amount per unit area of white content again being determined essentially by line-width modulation and detail being resolved by the aforementioned techniques of skewing and weighting of individually tailored elements of imagery.

In a ganged array, the three color primaries indicated here as can be applied simultaneously after the first few advancements, and hence, no time is lost, as would be the case with a single-array machine.

Printing a panchromatic page in as little as twenty seconds can be made practicable using the multi-array anvil e.g. **50** sets, and running anvil drive at **10** in. per, (typically the inking means of this array of four would span less than an inch and be part of a highly portable machine overall), and a quarter of this time, namely five seconds, for a monochromatic page. In this mode, the heavier multiple-array units can deliver a monochromatic page in considerably less than a second.

It is evident that those skilled in the art may now make numerous other uses and modifications of,, and departures from the specific embodiments described herein without departing from the inventive concepts. Consequently, the invention is to be construed as embracing each and every novel feature and novel combination of features present in, or possessed by, the apparatus and techniques herein disclosed and limited solely by the scope and spirit of the appended claims.

What is claimed is:

1. Process printing apparatus comprising plural transducing blade means,

each blade means having a longitudinally elongated in a direction parallel to a scanning direction continuous leading edge surface portion for hammering movement in a direction perpendicular to said scanning direction toward a recording substrate back face and being activatable by passage of magnetic field and electric current through the blade means to induce said hammering movement,

said leading edge surface portions being in stacked relationship,

reaction anvil means having an elongated forward surface angled with respect to and confronting said leading edge surface portions to receive pressing of a front face of said recording substrate,

means for relatively displacing said anvil means and said stacked leading edges along a longitudinal path generally parallel to said scanning direction while preventing movement of the anvil means in a predetermined direction perpendicular to said scanning direction,

means for passing a common magnetic field through the blade means,

and means for selectively applying pluralities of electrical signals as current through selected ones of said blade means to selectively displace any combination of a plurality of said leading edge surface portions toward said anvil means.

2. Process printing apparatus in accordance with claim **1** wherein said blade means have their leading edge surface portions in a substantially common plane.

3. Process printing apparatus in accordance with claim **2** wherein

said means for selectively displacing leading edges comprise

means for selectively displacing said blades by selective passage of electric current therethrough in a direction parallel to the leading edge thereof,

and means for applying a magnetic field to the pack at an angle to said leading edges.

4. Process printing apparatus in accordance with claim **2** wherein said blade means comprise a pack of primary blades having said leading edges, and

said means for selectively displacing leading edges comprise,

a seconday pack of blades with individual blades of said secondary pack drivingly interconnected to corresponding individual blades of the aforesaid pack of primary blades,

and means for selectively applying electric current to blades of said secondary pack and means for passing a magnetic field through said secondary pack.

5. Process printing apparatus in accordance with claim **2** wherein

said blade means comprises essentially frictionless blade mounting means which allow said hammering movement.

6. Process printing apparatus in accordance with claim **5** wherein

said mounting means comprise plural fixed structure elements spaced along the blade length and spring means interconnecting each of said blades individually to a plurality of said fixed structure elements.

7. Process printing apparatus in accordance with claim **6** wherein

said fixed structure means comprise a first array of pins distributed through said pack and skewed with respect to said leading edges and stacks of collars on each pin,

each blade having portions mounted on said collars and spring strip extensions between said portions and the balance of the blade body.

8. Process printing apparatus in accordance with claim **7** and further comprising

a second set of pins distributed through said pack and extending parallel to the aforesaid first array of pins, means defining pairs of blade stops straddling pins of aid second array to set limits of hammering forward movement and return for said blades.

9. Process printing apparatus in accordance with claim **2** and further comprising,

means defining spring strips with each blade adjacent to the leading edge surface portions thereof.

10. Process printing apparatus in accordance with claim **1** and further comprising, means forming springs within the body of each blade means, and

means forming hammering motion stop limits for each of said leading edge surface portions.

11. Process printing apparatus in accordance with claim **1** and further comprising

means forming a flexible curtain between said leading edges and the path of movement of a recording substrate.

12. Process printing apparatus in accordance with claim **1** and further comprising

multiple arrays of said leading edges,

the arrays being stacked in the direction of feed of the recording substrate.

13. Process printing apparatus in accordance with claim **12** and further comprising

multiple reaction anvils stacked in the direction of feed of the recording substrate and confronting said multiple arrays of leading edges.

14. Process printing apparatus in accordance with claim **13** and further comprising

means forming multiple reaction anvils at each of said stacked anvil locations interchangeable at any given anvil location during operation of the apparatus.

15. Process printing apparatus inn accordance with claim **1** and further comprising

means for feeding ink to said reaction anvil means.

16. Process printing apparatus in accordance with claim **15** wherein

said ink feeding means comprise means defining a passage terminating in an array of exit ports,

said reaction anvil means comprise an anvil roller arranged between aid array of exiit ports and a path of movement of a recording substrate and means for rotating said roller during said relative displeacement of said anvil means.

17. Process printing apparatus in accordance with claim **16** and further comprising

means forming absorbent and expansible packing between said exit ports and said roller.

18. Process printing apparatus in accordance with claim **17** and further comprising

means for feeding a recording substrate between said stacked leading edges and said reaction anvil means.

19. Process printing apparatus in accordance with claim **1** and further comprising

means for feeding a recording substrate between said stacked leading edges and said reaction anvil means.

20. Process printing apparatus in accordance with claim **1** and further comprising

plural reading means each of which comprises a radiant energy source and a detector,

font means,

means for relatively displacing said reading means and font means coactively with said carriage movement,

means for deriving electrical signals from said detectors as a function of radiant energy detected thereby,

and means for activating individual ones of said transducers electrically to drive their respective hammer edges in response to generation of electrical signals by correspondinng individual detectors of said plural reading means.

21. Apparatus in accordance with claim **20** wherein

said font comprises overlapping plural arrays of related characters

and said reading means comprises shift means for selecting which of said arrays is to be read.

22. Apparatus in accordance with claim **20** wherein said reading means comprises

means defining a stack of separate optical paths,

means defining common light source means for said paths,

means defining separate photoelectric detectors for said paths.

23. Apparatus in accordance with claim **22** wherein

said optical paths are defined by a stack of spaced opaque baffles separated by plural concentric transparent rings,

the detectors being radially within the innermost ones of said concentric rings and said common light source being outside the outermost ones of said concentric rings,

said font means being radially between said light source and outermost rings.

24. Apparatus in accordance with claim **23** wherein

plural common light sources are distributed around the periphery of aid outermost ring and said relative displacement means move the light sources around said periphery.

25. Blade pack apparatus for use in process printers or the like comprising

means defining a set of longitudinal elongated thin blades with faces and elongated lateral leading edges,

the blades being arranged in a pack with close spacing between adjacent blades with their leading edges essentially parallel to each other and in a common plane,

means for tying the blades together in said pack arrangement, and

means for effecting selective movement of individual blades in a variety of sequences and in a variety of numbers of simultaneously moved blades and comprising means for passing a magnetic field through the pack in a direction substantially perpendicular to the blade faces and means for selectively passing electrical current through selected blades to induce lateral blade movement.

26. Blade pack apparatus in accordance with claim **25** and further comprising

means for limiting blade lateral movement.

27. Blade pack apparatus in accordance with claim **26** wherein

said means for limiting blade lateral movement comprise a plurality of stop means passing through the blades,

said stop means being spaced form each other and distributed through the plane of each blade,

each of said blades having portions thereof formed to engage said stop means at preselected limits of blade movement and to clear said stop means between limits of blade movement.

28. Blade pack apparatus in accordance with claim **26** and further comprising

spring defining means interconnecting said elongated leading edges with their respective blades.

29. Blade pack apparatus in accordance with claim wherein said tying means comprise plural pins secured to fixed structure of the apparatus passing through said blades at distributed locations therein and plural collars mounted on each of said pins,

said collars supporting said blades in said tied arrangement,

said blades having portions engaging said collars and spring strip portions interconnecting the collar engaging portions of the blades with the blade bodies.

30. Blade pack apparatus in accordance with claim **25** wherein

said means for effecting selective movement comprise plural sets of electric terminals with a pair flexibly connected to ends of each blade to pass electrical current through said blades in a direction parallel to said blade leading edges.

31. Blade pack apparatus in accordance with claim **30** wherein

said blades are sandwiched between magnetic pole defining means and said stop means and pins are anchored in said magnetic pole defining means.

32. Blade pack apparatus in accordance with claim **31** and further comprising

magnetic yoke means interconnecting said pole defining means.

33. Blade pack apparatus in accordance with claim **42** wherein

said magnetic yoke means comprise a wall spanning rear edges of said blades and having gas passage means therein.

34. Blade pack apparatus in accordance with claim **25** and further comprising

means defining a flexible curtain passing along said blade leaading edges.

35. Blade pack apparatus in accordance with claim **25** and further comprising

energy absorbing means for cushioning backward blade movement.

36. Process printing apparatus comprising the blade pack apparatus of claim **25** in combination with anvil defining means arranged to confront said leading edges and means for feeding print medium between said blade pack and anvil.

37. Process printing apparatus in accordance with claim **36** wherein

said anvil defining means comprise an elongated rod arranged orthogonally to the direction of blade elongation.

38. Apparatus in accordance with claim **37** and further comprising

flexible curtain means between said edges and said rod,

means for feeding paper between said curtain and anvil,

and means in said curtain clear of the paper feed path defining at least one recess for rod storage.

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