

March 29, 1966

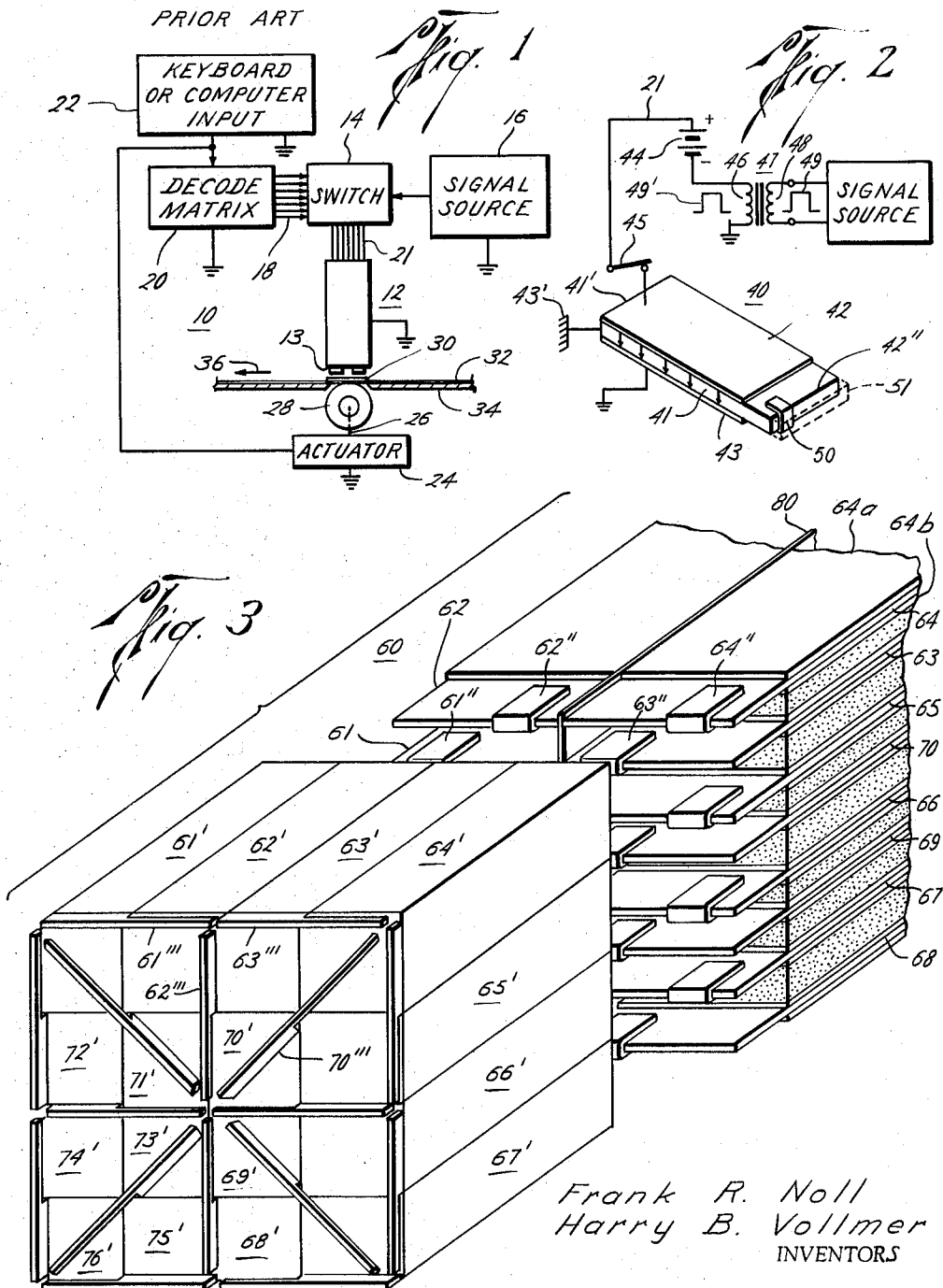
F. R. NOLL ET AL

3,242,855

ELECTROSTRICTIVE PRINTER

Filed Oct. 3, 1963

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

Fig. 5

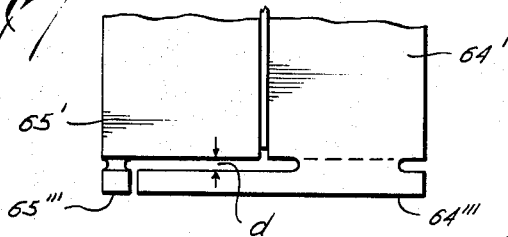


Fig. 4

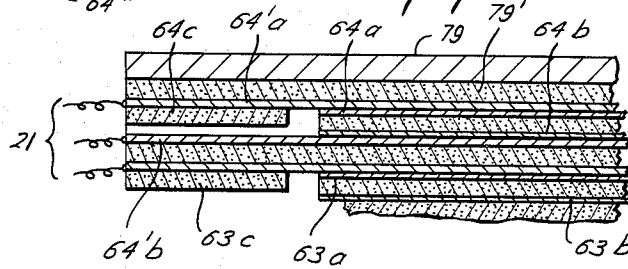


Fig. 6

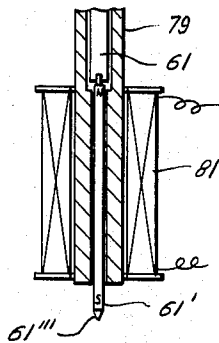


Fig. 7

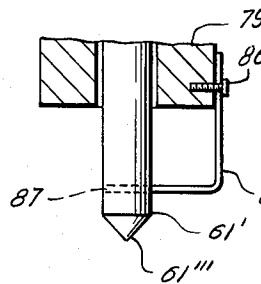


Fig. 9

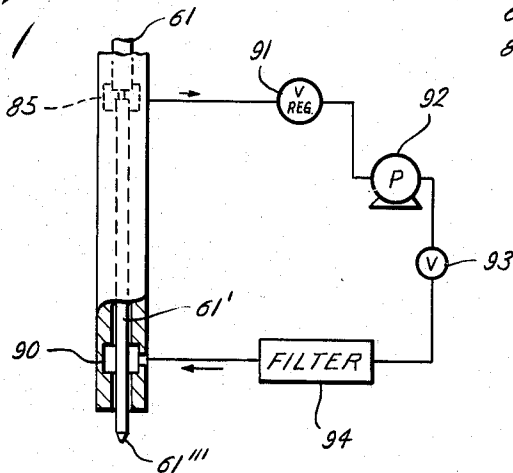
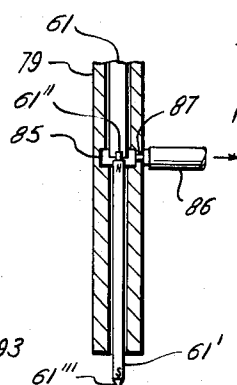


Fig. 8



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ELECTROSTRICTIVE PRINTER

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This invention relates to printing machines and more particularly to solid-state printing machines in which the actuating elements are composed of electrostrictive material.

In the application, Ser. No. 93,461 of David R. Williams and now Patent No. 3,112,693, issued Dec. 3, 1963, a new solid-state printer, having a relatively small number of moving parts, is described.

The solid-state printer for printing characters on the surface of a work member described in said patent application comprises a type assembly including one or more type elements disposed in a predetermined manner adjacent to the printing surface of a work member. The type assembly and the work member are susceptible of relative displacements. Each type element is composed of an elongated member terminating in a type character. The elongated member is of an electrostrictive material with suitably disposed electrodes thereon for sustaining a difference of potential therebetween. One end of each elongated member is fixed to the housing of the type assembly and the other end is free to move in response to an applied predetermined voltage to its electrodes thereby directly disposing its type character for a printing operation.

Although the printer described in said patent application affords satisfactory results, yet it is often desirable to print under conditions which cause excessive variations in the separation between the type assembly and the printing surface.

Accordingly, it is an object of this invention to provide a new and improved solid-state type assembly which includes a minimum of components and which affords reliable printing under variable operating conditions.

Another object of this invention is to provide a new and improved solid-state type assembly which can be economically manufactured.

These and other apparent objects of this invention are achieved by providing a solid-state printing apparatus including a type assembly comprising at least one electrostrictive actuating element for hurling a free-mass type head from a rest position to a printing position. The type head is provided with a type character disposed opposite and adjacent to a printing surface. In one embodiment, the type head is returned to its rest position by an electromagnet. In another embodiment, the type head is returned by a suitable spring. Yet in a preferred embodiment, the type head is returned by creating a vacuum chamber between the tips of the type heads and the movable ends of the actuating elements.

Further advantages and features of this invention will become apparent upon consideration of the following description taken in conjunction with the drawings wherein:

FIG. 1 is a known solid-state printer assembly;

FIG. 2 shows an electrostrictive actuating element which may be used in the preferred embodiment of this invention and a schematic diagram of a suitable driving circuit for the actuating element;

FIG. 3 is a perspective view of the type assembly of the present invention showing the arrangement of the electrostrictive actuating elements and of their corresponding type heads;

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FIG. 4 is a partial, cross-sectional view of the actuating elements shown in FIG. 3;

FIG. 5 is a partial end view of two adjacent type heads and type characters shown in FIG. 3;

FIG. 6 illustrates an electromagnet for returning a type head to its rest position;

FIG. 7 illustrates a spring for returning a type head to its rest position;

FIG. 8 illustrates a vacuum chamber for returning a type head to its rest position; and

FIG. 9 shows suitable pressure creating equipment for use in FIG. 8.

Referring to FIG. 1 there is shown a known, solid-state, electrostrictive printer generally designated as 10. The printer comprises a solid-state type assembly 12 (hereinafter referred to simply as "type") adapted to form different characters on a typing surface. A switching system 14 couples a source of potential 16 and the output lines 18 of a decoding matrix 20 to the input lines 21 of the type 12. Matrix 20 is controlled by the output signals from a keyboard 22 or other suitable source such as a computer. The keyboard 22 may provide either electrical or mechanical signals to matrix 20 thereby energizing one or more of its output lines 18 which, in turn, cause switch 14 to couple the source of potential 16 to a number of input lines 21 to the type 12. The keyboard 22 may be also coupled to an electromechanical actuator 24 which acts through a mechanical linkage 26 to raise a striking bar or roller 28 against type 12. An inked ribbon 30 and a suitable paper 32 may be disposed between the type 12 and the roller 28. The paper 32 typically rides upon a support member 34 which is driven in the direction indicated by the arrow 36.

The type 12 includes a plurality of thin, elongated electrostrictive bars (not shown). One end of each bar is fixedly secured to the casing of type 12. The other end opposite to the roller 28 is terminated with a type character. Only two such type characters 13 are shown in FIG. 1 as protruding from the casing of type 12.

In a typical operation of the known printer, a desired character is formed by elongating certain bars while contracting the others. This is achieved by suitably energizing respective ones of lines 21 with potentials of predetermined magnitudes and polarities. After the characters are formed, the actuator 24 causes the roller 28 to raise the paper 32 and the inked ribbon 30 against the type 12. In this manner direct printing may be achieved. It will be readily appreciated that in practice it may be difficult to maintain the close tolerances necessary for direct printing. For example, if the thickness of the paper is nonuniform or the support 34 becomes slightly vertically displaced even by one or two mils, reliable printing may be difficult to obtain.

Another undesirable limitation of the known printer is the difficulty in obtaining rapid printing. In fast printing, the paper is continuously moving and the printing is done "on the fly." As a result, a shearing action takes place between the moving paper and the free end of the electrostrictive bar which carries the type character. This shearing action may cause frequent breaking of the tip of the electrostrictive bar. The above and other limitations of the known solid-state printer are avoided by the present invention, for a better understanding of which, a brief review of electrostrictive effects is given in conjunction with the description of FIG. 2.

The phenomenon of electrostriction wherein some materials experience an elastic strain as a result of an applied electric field is well known. Such materials as lead zirconate-titanate having a displacement on the order of 3 mils per inch for a field strength of 50,000 volts per inch are especially suitable for maximally employing the elec-

trostrictive effect. Another material which may be used is barium titanate.

In FIG. 2 is shown a solid-state actuator 40 which comprises as elongated thin, rectangularly-shaped slab 41 of an electrostrictive (typically ferroelectric) material. Secured to or deposited on both faces of slab 41 are conductive electrodes 42, 43 extending from one end 41' to nearly the other end 42''. End 41' of slab 41 is fixedly secured to a support member 43', preferably a non-conductor. The other end 42'' is free to elongate in response to a potential applied across electrodes 42, 43. A typical bar 41 may be made of lead zirconate-titanate purchased from the Clevite Corporation under the name of PZT-5B. Typical dimensions for bar 41 may be .140 inch wide, .010 inch thick, and 5 inches long. The electrodes 42, 43 may be made of a silver material fired on during the fabrication of the bar 41. Care is taken during the fabrication of the bars to insure that the electrodes are not shorted between their edges.

In FIG. 2 is also illustrated a driver for driving the electrostrictive bar 41. In accordance with one mode of operation, a D.C. potential source 44 is connected to the upper electrode 42 through a conductor 21 and a switch 45. The negative terminal of the power supply 44 is connected to the lower, grounded electrode 43 through the secondary winding 46 of a transformer 47 having a primary winding 48. In its neutral quiescent position, the bar 41 is contracted by the application to its electrodes of a bias voltage on the order of 250 to 300 volts. To actuate bar 41, a pulse 49 is applied to the primary winding 48 causing a corresponding pulse 49' to develop across the secondary winding 46. Pulse 49' is of such amplitude as to overcome the bias furnished by power supply 44 and to apply a sufficient potential difference across electrodes 42, 43 in an opposite direction. A typical amplitude of pulse 49' is on the order of 500 volts. The duration of pulse 49' depends on the resonant frequency of bar 41 which, for the above-given dimensions, is on the order of 7 kilocycles per second. With such a resonant frequency, the pulse duration may be on the order of .07 millisecond. It will be appreciated that some time interval is necessary for the bar 41 to elongate and to return to its rest position. A typical time interval for the bar 41 to elongate to the position shown by the dotted lines 51 is on the order of .07 millisecond. A substantially equal time interval is required for the bar to return to its contracted rest position.

In accordance with the present invention, the electrostrictive actuating transducer 40 is used to hurl a free-mass type head on to the printing surface 32. The free moving end 42'' of the drive bar 41 is provided with a generally U-shaped metal striker 50, preferably attached with an adhesive, as shown in FIG. 2. Striker 50 substantially eliminates the wear from the end 42'' of bar 41. In the area of the striker, the electrodes 42, 43 are removed as by sandblasting to eliminate the possibility of shorting out the electrodes.

Depending on the desired type characters, a number of free-mass type heads and an equal number of electrostrictive actuators therefor are provided.

In FIG. 3 is illustrated an alpha-numeric type assembly 60 including sixteen actuating bars 61-76 arranged in two parallel stacks separated by an insulating sheet 80. The type assembly 60 includes an equal number of type heads 61'-76' disposed immediately adjacent and opposite to the actuating bars 61-76. Each actuating bar carries a metallic striker for actuating its associated type head. Thus, bar 61 is provided with a striker 61'' for actuating its corresponding type head 61'. Similarly, bar 62 is provided with a metallic striker 62'' for actuating its corresponding type head 62', etc.

As shown in FIGS. 3 and 4, each electrostrictive bar has two electrodes designated with the same numeral as the bar to which they are attached but with a subscript "a" for the upper electrode and a subscript "b" for the

lower electrode. Thus bar 64, for example, has an upper electrode 64_a and a lower electrode 64_b. The manner of connecting electric wires to the respective electrodes is illustrated in FIG. 4. To each electrode is pressed a plate made of a good conductive material, such as copper. Each plate may have the same width as an electrode but preferably should extend a distance beyond its associated electrode. Each plate is assigned the same numeral as its corresponding electrode and a prime ('). Thus plate 64_a' is in electrical contact with electrode 64_a and plate 64_b' with electrode 64_b. Sandwiched between plates 64_a' and 64_b' is a short insulating strip or plate 64c as shown. Similarly, sandwiched between plates 65_a' and 65_b' is an insulating strip 64c, etc. The function of the insulating plates 61c-76c is to prevent the plates from becoming short circuited. Although in FIG. 4 the plates are shown as being separate members from the electrodes but in electrical contact therewith, it will be appreciated that the plates and the electrodes may form a single member. To each plate in electrical contact with an electrode is connected a wire 21. When a voltage is applied across the lower and upper electrodes of an electrostrictive bar, the bar will either contract or elongate depending on the polarity of the applied voltage. The forces developed by the elongation of the electrostrictive bars are used to actuate the free-mass type heads 61'-76'.

Although the geometric configuration of the free-mass type heads 61'-76' is not critical, it is preferable to employ rectangularly-shaped steel bars, the optimum dimensions of which may be determined experimentally. In the preferred embodiment, steel bars of .06 by .095 and 8 inches long provided the optimum mass required to develop the necessary forces and dynamic characteristics at all operating speeds. Each bar is terminated with a type character. Type head 61' is provided with a type character 61'', type head 62' with a type character 62'', etc. When the type heads are assembled together as shown in FIG. 3, each head is free to elongate relative to the remaining heads (just as a free-mass). The type characters 61''-76'' form an alpha-numeric matrix. Each type character has a narrow and a wide portion, the wider portion being fixedly secured, in any suitable manner, to the lower end of the type head. The type character may be welded to the type head, or the type head with its type character may be machined from one piece of steel bar. The orientation of each type character on its type head depends on the relative position of the type head within the alpha-numeric matrix. Each type character extends over the surface area of an adjacent type head as shown in FIG. 3. To allow for the relative displacement between adjacent type heads, each narrow portion of each type character is raised by a distance *d* above the lower base of the adjacent type heads. Distance *d* is greater than the maximum expected travel distance of a type head.

In FIG. 5 are illustrated two adjacent type heads 64' and 65' with their corresponding type characters 64'' and 65''. As can be seen from the drawing, type head 64' is free to move relative to type head 65' and type head 65' is free to move relative to type head 64' because the maximum length of travel of type head 65' is less than the separation *d*.

It will be appreciated from the description of FIGS. 3 through 5 that because the type characters may be variously oriented on the type heads, the type 12 may be compactly assembled in any suitable housing. A housing 79 is shown in cross-section in FIG. 4 and may be of an insulating material. If the housing is of a conductive material, an insulating envelope 79' may be also provided.

Because the type heads 61'-76' are not fixedly secured to their corresponding actuating bars, it is necessary to provide means for returning the actuated type heads to their rest positions after a printing operation. To develop a maximum printing force, it is preferred that, in its

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rest position, each type head be in contact with its respective drive bar. Several methods may be used for returning the type heads to their rest positions as will be described in conjunction with FIGS. 6 through 9. To simplify the drawing, each type assembly is shown as including a single actuating bar 61 and a corresponding type head 61'. It will be understood, however, that in practice the principles hereinafter described are applicable to type assemblies with more than a single type head.

The first method makes use of the earth's gravitational force. Obviously, when employing this method, the type assembly 12 must be inverted from the position shown in FIG. 1. The printing is done upwardly. When the type assembly is inverted, each of the free-mass type heads 61'-76' is free to fall to its rest position after a printing operation. For a single type head, this method is satisfactory at all printing speeds. With a single type head, it was possible to print up to 500 marks or more per second. For a multi-type head, the gravity return method performed satisfactorily at low printing speed only. At higher printing speeds, due to sticking between the type heads, the printing may become erratic.

Another method for returning the type heads to their rest positions makes use of an upwardly directed lifting force created by a magnetic field. As shown in FIG. 6, this force may be created by a direct current sent into an electromagnet 81 which surrounds the nonmagnetic housing 79 around the type head 61'. Obviously, instead of an electromagnet 81, a permanent magnet could equally be employed as will be understood by those skilled in the art. The magnetic return principle is very satisfactory if only one type head is employed. In a multi-type head assembly, the type heads tend to cluster together whenever a magnetic field is developed. Because of this clustering, a frictional force is developed between the type heads of sufficient magnitude to prevent the individual type heads from freely returning to their rest positions. The clustering problem may be overcome by the use of permanent magnets for the type heads. By orienting the poles of the type heads in the same direction, i.e. all the north poles together and all the south poles together, the individual type heads would repel each other and no clustering would take place.

Another method which may be employed for returning the type heads to their rest positions makes use of the resilient forces developed by suitable springs. In FIG. 7 is shown a cantilever spring 85, one end of which is secured by a screw 86 to the housing 79 and the other end is snugly inserted in a hole 87 defined by the tip of the type head 61'. Although this method is satisfactory at all printing speeds, it is time consuming to equalize the tensions on all of the springs. If the tensions are not equalized, uniform contrast on the printing surface is difficult to achieve.

The preferred method for returning the type heads to their rest positions is based upon creating a vacuum in a plenum chamber 85 defined in the housing 79, as shown in FIG. 8. The vacuum may be created by coupling a vacuum pump (not shown) to a conduit 86 fitted to a coupling 87 in the wall of the housing 79. The plenum chamber 85 is centered around the metallic strikers 61'-76'' of the electrostrictive bars. In operation, after the type head 61' is hurled by the metal striker 61'' on the actuating bar 61, the atmospheric pressure exerted against the bottom tip of the type head 61' forces the type head to return to its rest position against the metal striker 61''. Satisfactory operation at all operating speeds was obtained with a vacuum ranging between five to twelve inches of mercury.

It will be appreciated that because the opening in the housing 79 near the bottom tips of the type heads is not airtight, air will be drawn from that opening into the vacuum chamber 85. This may result in the accumulation of dust between the type heads causing undesirable sticking therebetween. This can be avoided as shown in

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FIG. 9 by providing another plenum chamber 90 at the lower end of the housing 79 and creating a pressure therein. Although the pressure creating means may be independently coupled to the chamber 90 from the vacuum creating means, in practice it is preferable to use a single pump for establishing the desired vacuum and the desired pressure. In a typical installation between chambers 85 and 90 were coupled a regulating valve 91, a pump 92, another regulating valve 93 and a filter 94, all connected in series. In this manner, either the vacuum in chamber 85 or the pressure in chamber 90 may be independently controlled. The pressure created in chamber 90 prevents dust particles from entering the housing 79.

To summarize the operation of the solid-state printer, the electrostrictive bars are contracted, in their rest positions, by applying a bias voltage across their respective electrodes. To print a character on the printing surface of paper 32, a signal from the keyboard 22 causes certain ones of lines 21 to receive actuating signals from the signal source 16 which may include biasing means and pulse supplying means. The application of pulse actuating signals to the electrodes of an electrostrictive bar causes its striker to hurl its corresponding type head onto the paper 32. In the rest position, the type head rests against the corresponding bar's striker. Several methods may be used for returning the type heads to their rest positions. Those described include the gravitational-return-method, the magnetic-return-method, the spring-return-method. The preferred method, however, is the vacuum-return-method.

While there have been shown and described the fundamental novel features of the invention as applied to the preferred embodiment, it will be understood that various omissions and substitutions may be made by those skilled in the art without departing from the spirit of the invention. It is the intention, therefore, to be limited only as indicated by the scope of the appended claims.

What is claimed is:

1. An apparatus for printing characters on a printing surface comprising:

a type assembly having a housing including at least one type head and an actuating transducer,

said type head being structurally free of said transducer and capable of relative displacement with respect thereto to engage said printing surface,

said type head defining a type character for printing on the printing surface,

said actuating transducer including an elongated member comprising an electrostrictive material, one end of said elongated member being fixed to said housing and the other end being movable with respect thereto, said other end of the actuating transducer being disposed in operative relationship with said type head to impart displacement thereto,

electrode means joined to said elongated member, said other end of the transducer being movable in response to an actuating signal applied to said electrode means to displace said type head with respect to the transducer to engage the printing surface thereby impressing the type character on said printing surface.

2. The apparatus of claim 1 and further including electric energizing means coupled to said transducer for selectively applying actuating signals to said electrode means.

3. The apparatus of claim 1 and further including returning means coupled to said housing for returning said type head to its position of operative relationship with said transducer after the completion of a printing operation.

4. The apparatus of claim 3 wherein said returning means includes:

a first plenum chamber within said housing adjacent said other end of said elongated member, and means for applying a vacuum to said chamber.

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5. The apparatus of claim 4 further including:
 an additional plenum chamber within said housing adjacent said type head and remote from said first plenum chamber, and
 means for applying pressure to said additional plenum chamber to thereby prevent dust particles from entering said housing.
6. The apparatus of claim 3 wherein said returning means includes a magnet and said type head is composed at least in part of magnetic material.
7. The apparatus of claim 3 wherein said returning means includes a resilient spring coupled between said housing and said type head.
8. The apparatus of claim 3 and further including a metallic striker mounted on said other end of said elongated member.

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WILLIAM B. PENN, *Primary Examiner.*