

[54] HIGH SPEED LINE PRINTING APPARATUS

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 3,834,303.

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[51] Int. Cl.² **B41J 9/38**

[58] Field of Search **101/93 C, 121; 197/121,
 197/133; 226/195**

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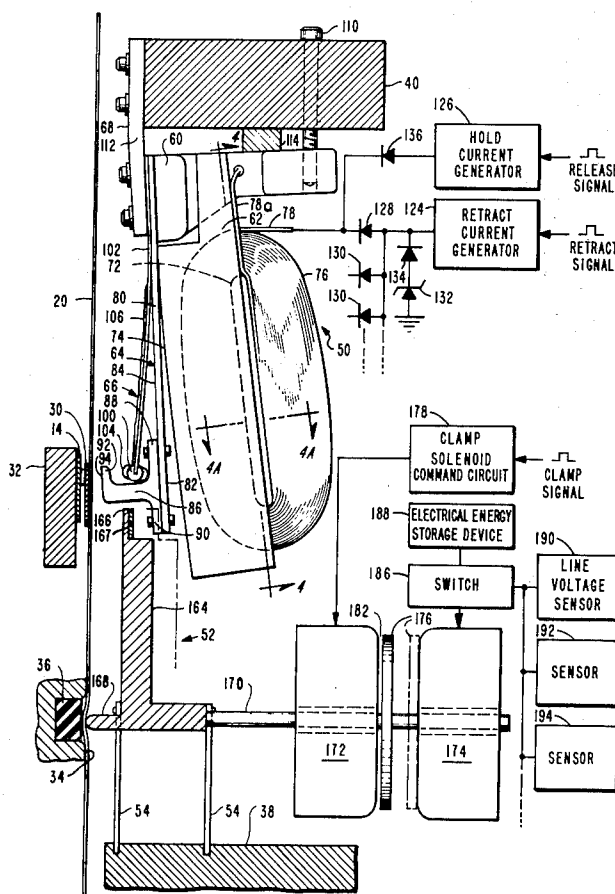
Attorney, Agent, or Firm—Fraser and Bogucki

[57]

ABSTRACT

A high speed line printer includes a print-receiving medium, a continuously moving type carrier, a ribbon positioned between the print-receiving medium and the type carrier, and a bank of hammer units having individually fired but simultaneously retracted hammers positioned adjacent the print-receiving medium. Each hammer is magnetically retracted and held against the force of a flat spring armature. Upon release of a hammer, the stored mechanical energy of the spring causes the hammer to be driven to a printing impact and a damper prevents subsequent printing impacts due to hammer oscillation. Each hammer unit comprises a pole piece with a convex pole face and a hammer which includes the flat spring armature secured at one end to the pole piece and an impact element mounted on the outer surface of the armature at the other, free end thereof. The damper has a low mass body which includes energy absorbing material and is spring biased to a normal position in contact with the impact element. The utilization of multiple impacts between the damper and hammer permits the damper mass to be reduced so as to reduce the total movable mass, thereby decreasing hammer flight time and increasing efficiency. An interposer is operable to prevent the printing of an unwanted line by inhibiting the flight of the hammers in the event of an error condition such as a power failure.

3 Claims, 14 Drawing Figures



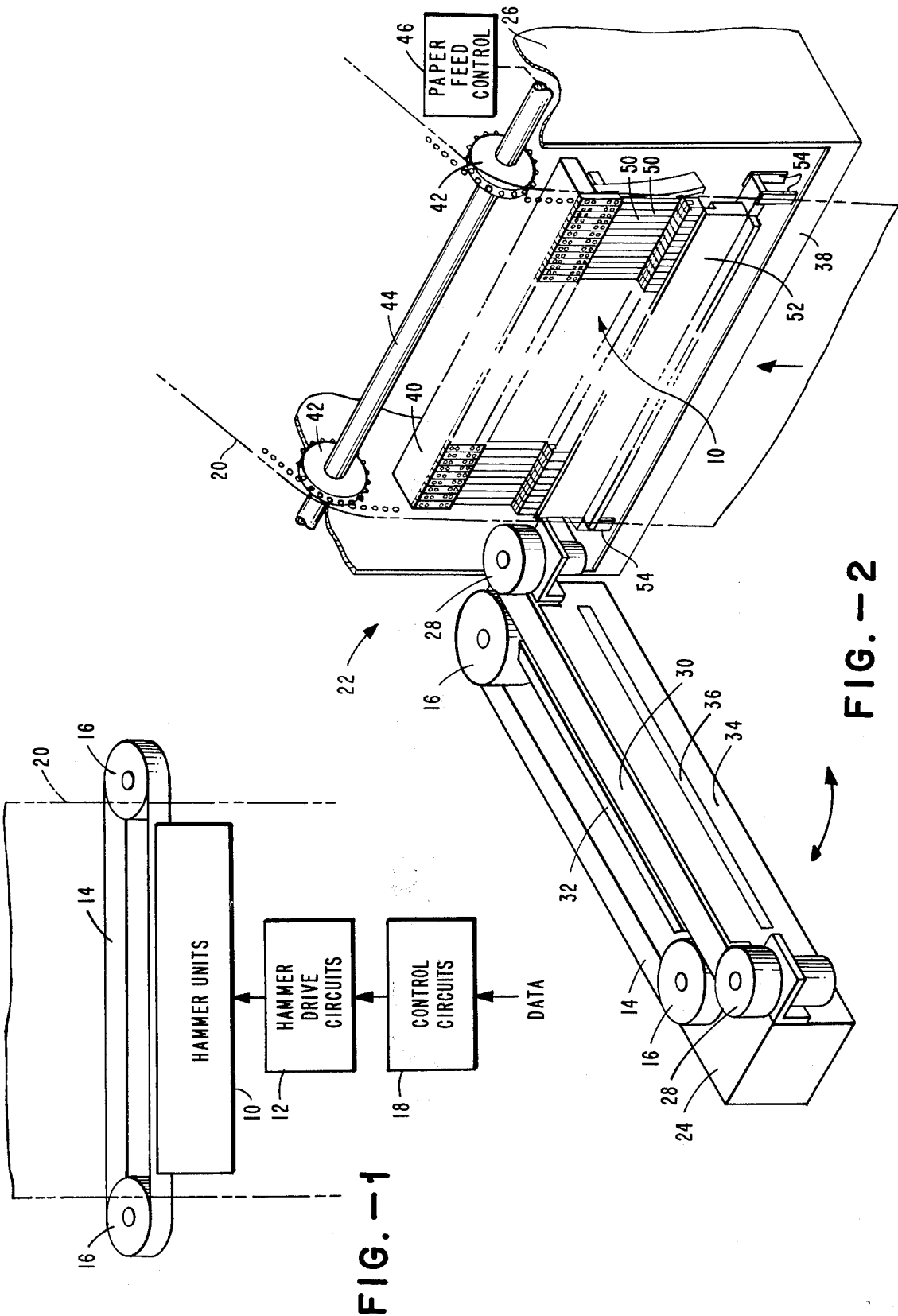
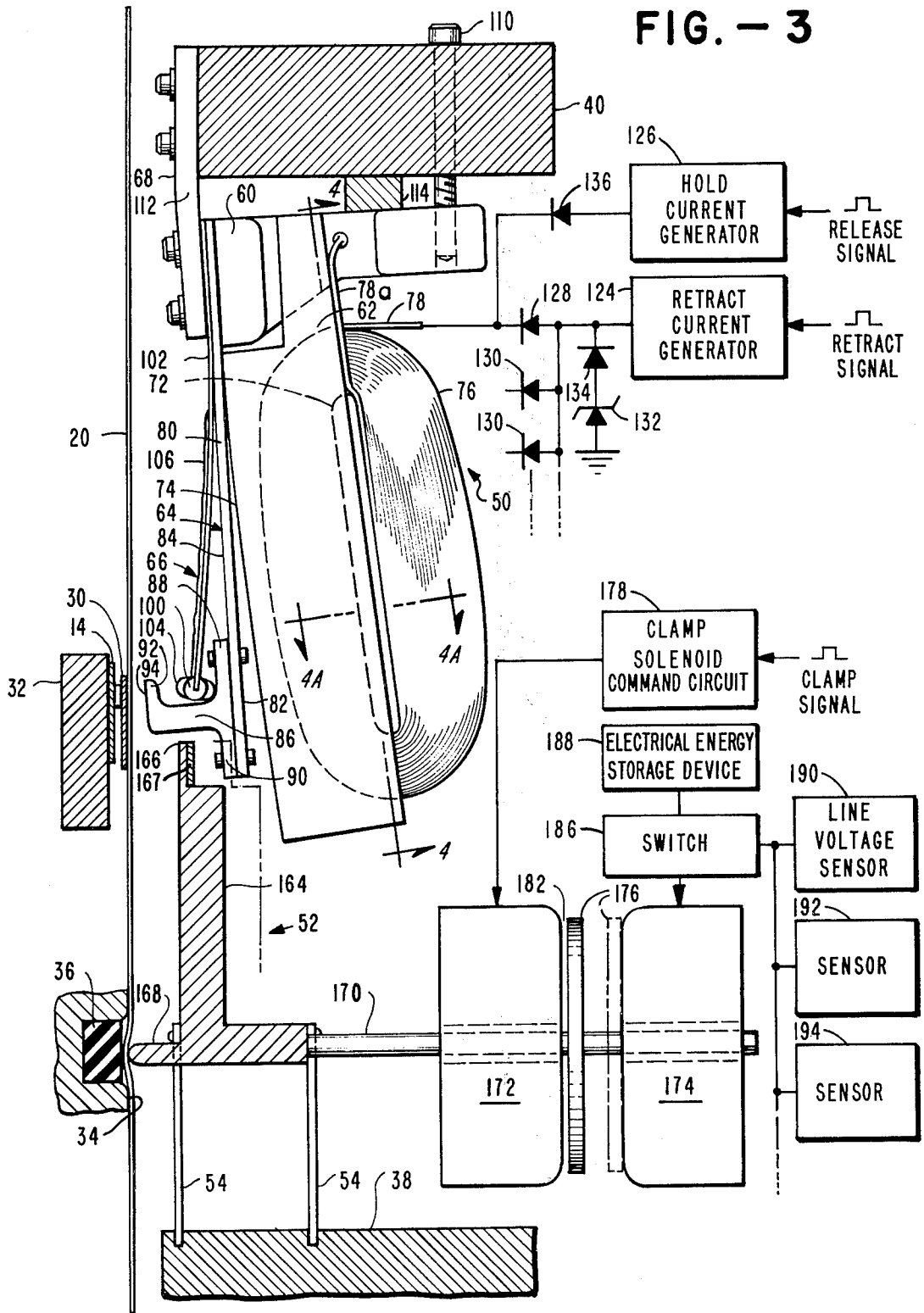


FIG. - 3



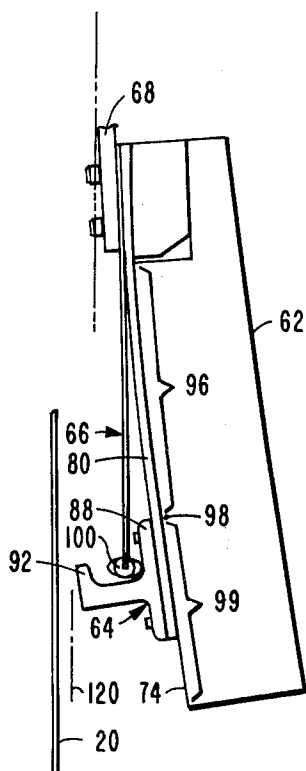


FIG. — 5A

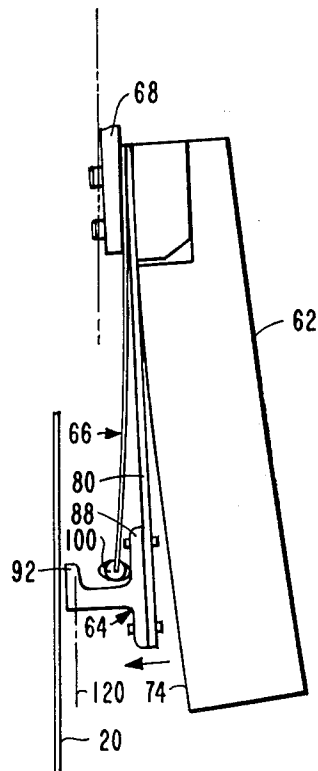


FIG. — 5B

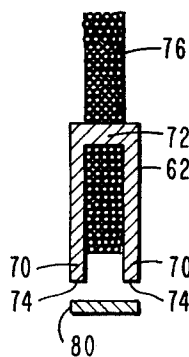


FIG. — 4A

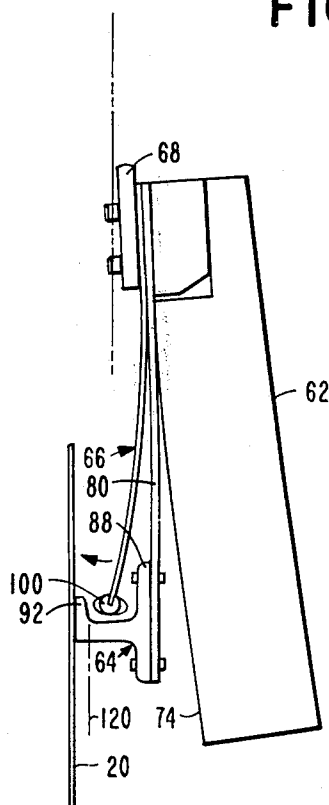


FIG. — 5C

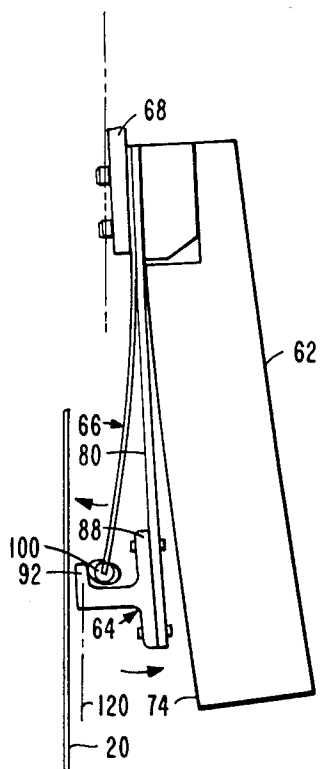


FIG. — 5D

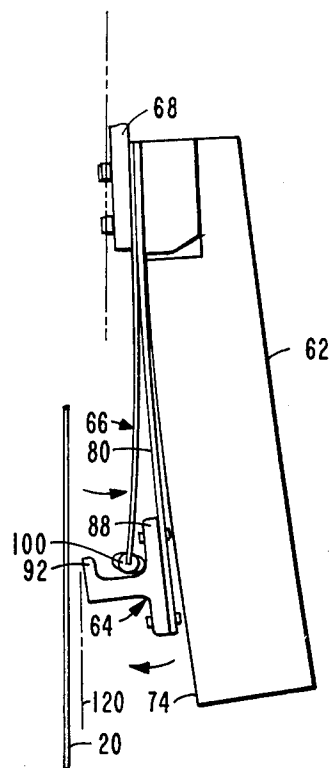


FIG. — 5E

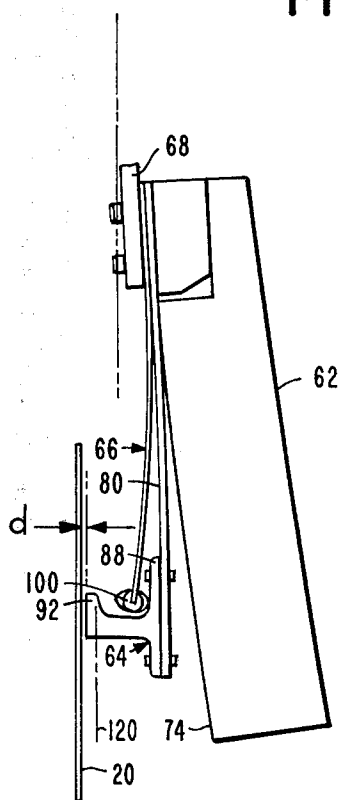


FIG. — 5F

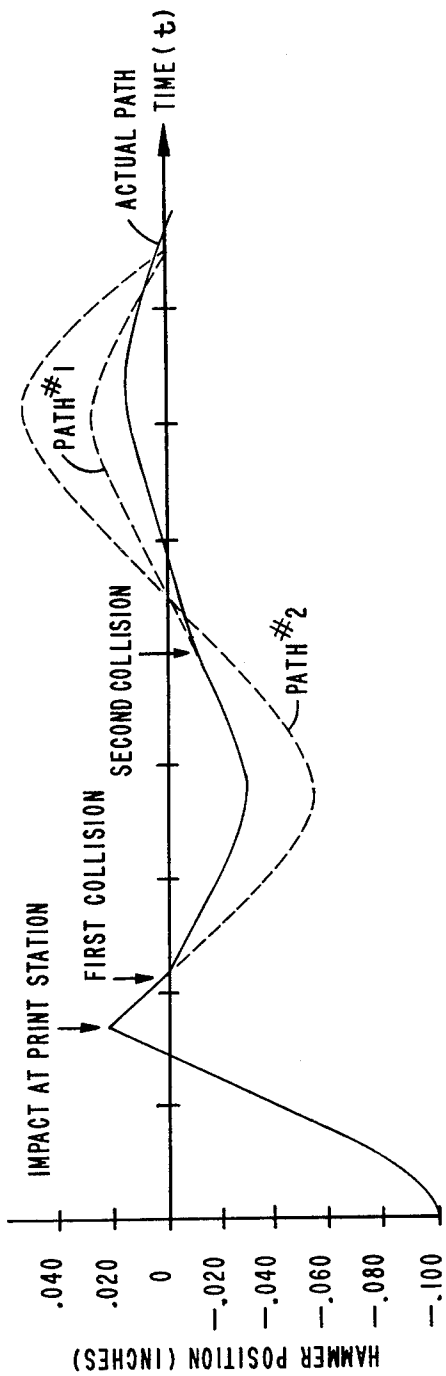


FIG.— 6

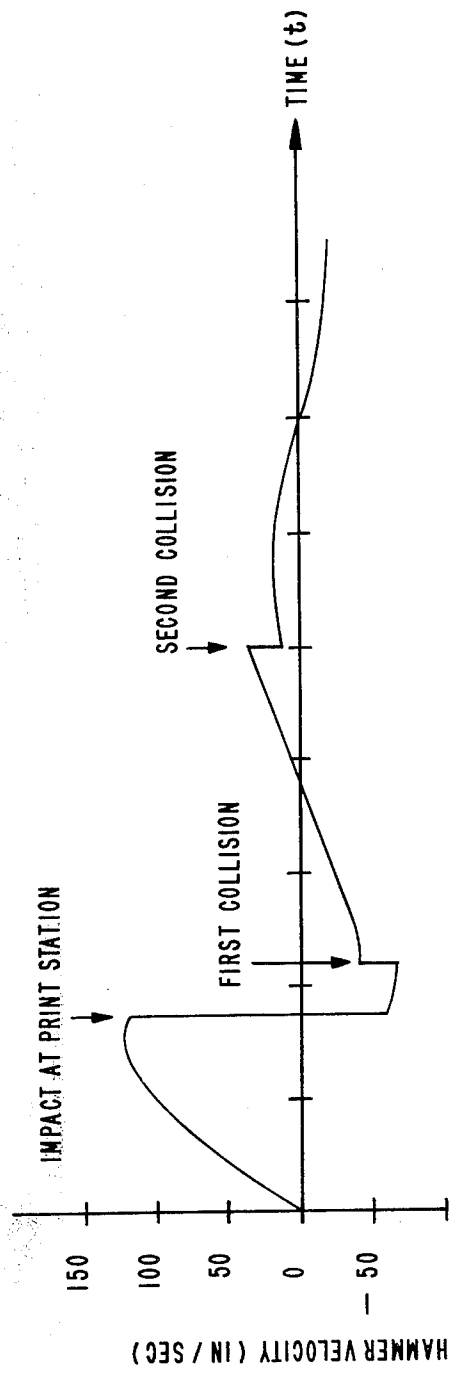


FIG.— 7

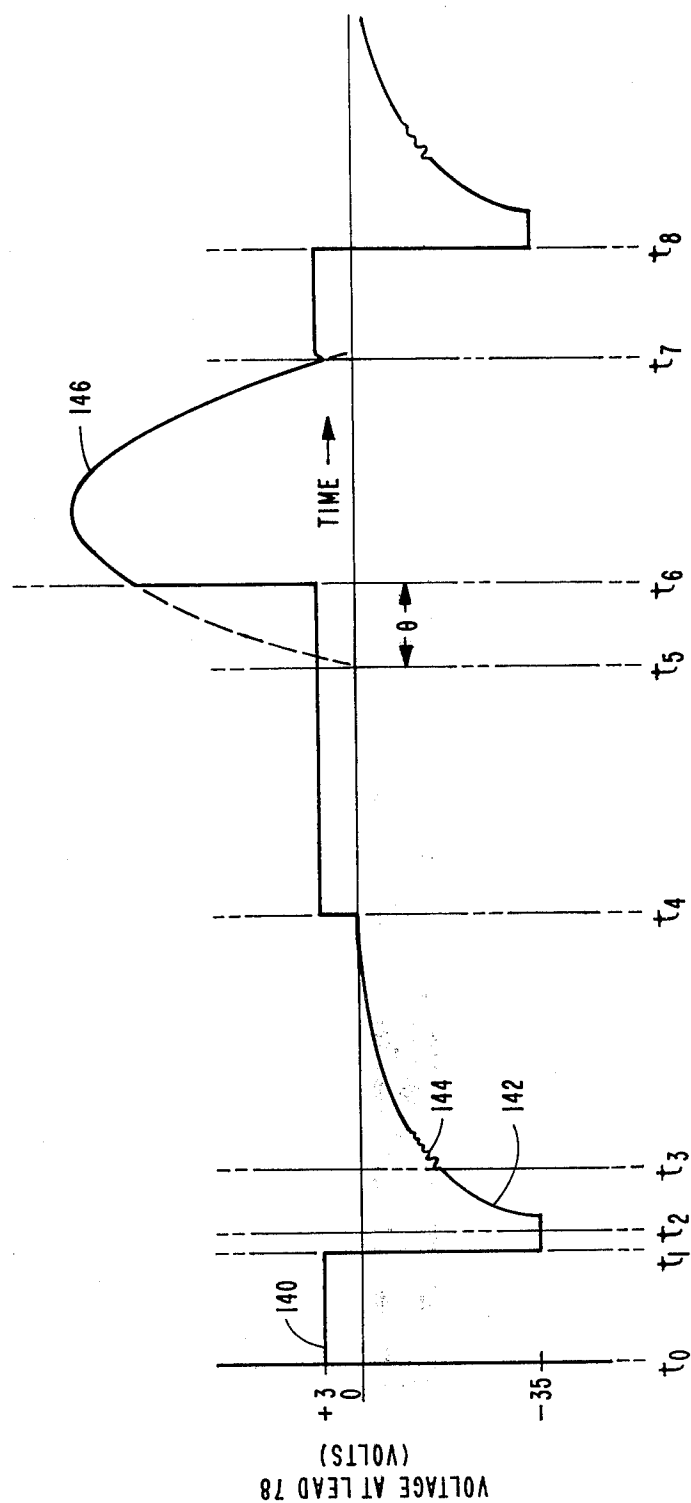


FIG. — 8

HIGH SPEED LINE PRINTING APPARATUS

This is a division of application Ser. No. 333,221, filed Feb. 16, 1973, now U.S. Pat. No. 3,834,303.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to high speed impact line printers and more particularly to improved hammer apparatus for use in such printers.

2. Description of the Prior Art

High speed impact line printers incorporate printing mechanisms utilizing character carriers typically in the form of type chains, bands or drums moving rapidly relative to an array or bank of controlled hammer units selectively operated in synchronization with the alignment of desired characters and print stations. A print-receiving medium such as a continuous paper web or form is fed incrementally through the printing mechanism between the character carrier and the hammer unit array. The most critical components in high speed impact line printers are the hammer units. These units basically comprise a hammer, consisting generally of an impact element mounted on a movable support, and means for firing the hammer.

A primary consideration underlying hammer unit design is the contact time during printing between the impact element and the paper form. The shorter the contact time the higher the allowable velocity of the characters relative to the hammer bank and the faster and clearer the print-out. More particularly, since the characters being impacted by the hammer are always in motion there will inherently be some smear of the printed image, the length of the smear being equivalent to the distance the character moves during hammer contact time. Thus, for a given hammer contact time, there is a compromise between the smear length and the speed of the character carrier; decreasing the speed of the character provides less smear but results in a decrease in the overall speed of the printer.

One parameter that directly affects contact time is the mass of the moving part of the hammer. It is this mass, in combination primarily with the spring constants of the paper form and the ribbon upon which the impact element of the hammer acts, that determines contact time. Since the printer manufacturer has no control over the spring constants of the paper form and ribbon it seems clear that to help achieve minimum contact time the moving mass of the hammer must be reduced to a minimum. Yet, in almost all prior art hammer units a significant portion of the moving mass is dead weight resulting in reduced efficiency and increased contact time. This holds true for prior art units whether fired electromagnetically, for example, by a solenoid or voice coil device, or mechanically, for example, by a spring device which stores the energy required for firing the hammer.

In line printers, accurate and consistent vertical and horizontal print registration are highly important and one of the primary sources of errors or variation in registration is the hammer itself. Since the characters on the chain, band or drum are constantly moving at high velocity, and minute variation in hammer flight time from nominal will result in a registration error of the printed character on the paper. Most hammer units of the prior art use some form of bearing, pivot or knife edge fulcrum to direct hammer head motion. These elements are naturally subject to changes in frictional

characteristics due to wear, dirt, lubricant breakdown and the like which in turn results in flight time variations. In hammers using a resilient backstop energy absorber, flight time variations eventually result by virtue of the permanent set taken on by the backstop and the consequent change in hammer starting position.

Due to the differences in thickness of the paper forms (ranging from single part to six part) that the printer must accommodate and the differences in impact energy required to properly print on each, some manner of impact energy adjustment may be desirable. In prior art apparatus, this is sometimes done mechanically by providing a mechanism to change the distance between the hammer faces and the characters or electrically by changing the hammer driving energy. These approaches all have drawbacks in that such changes must be made each time a form of different thickness is used.

A further requirement of high speed printers is the prevention of multiple impacts by the hammer. In certain hammer units of the prior art, this is achieved by affixing adjacent some portion of the hammer a resilient shock absorber adapted to be struck during the return movement of the hammer following impact. Other known hammer devices employ pivot bearings fabricated of resilient or elastomeric material which tend to dampen the motion of the hammer. Still others have hollow hammer heads filled with said, liquid, shot or other material which reacts inertially with the hammer head to damp oscillations thereof. Imprecision in flight time is introduced, however, and with respect to the use of particulate matter, wear due to abrasion becomes a significant drawback.

As already stated, hammer units are known using a stored energy spring principle and in which the hammers are magnetically retracted. However, magnetic crosstalk between nearby hammer assemblies has theretofore prevented optimum combinations of the high speed magnetic control and spring energy drive of the hammers. Magnetic flux generated by nearby hammer assemblies can unduly affect the release or flight time of a given hammer so that the moving type carrier is not in the desired position at impact. One arrangement seeks to reduce crosstalk by combining low energy magnetic hold with low speed mechanical retract. Another combines high energy magnetic firing with spring biased retract. Such systems are therefore not only complex and expensive due to the extra mechanism required but the recover and recycle time is unduly prolonged thereby limiting the speed at which the printer can operate.

In those systems in which the hammers are retracted and latched electromagnetically, there is often no provision for preventing the hammer from firing in the event of power loss or shut down. If a paper form is in place during such loss or shut down, the printing of an unwanted line results.

SUMMARY OF THE INVENTION

In general, hammer units in accordance with the present invention overcome many of the disadvantages of the prior art by utilizing an essentially frictionless hammer having a positive, non-varying (but adjustable) starting position so that the flight time for a given paper form thickness remains constant essentially indefinitely. Further the moving mass of the hammer is extremely low and is utilized with great efficiency in that the entire active length of the impact element support is used not only to store the firing energy but forms part

of a magnetic flux path generated to retract and latch the hammer.

In accordance with one exemplary form of a hammer unit of the invention, is provided a pole piece having a convex pole face and winding adapted to be coupled to an appropriate electrical circuit for selectively generating a magnetic flux within the pole piece. An elongated, flexible, magnetic armature, which may simply comprise a thin, flat spring of magnetic material, has one end secured in fixed relationship to the pole piece and another, free end. The armature has an inner surface in opposed relationship to the pole face and an outer surface. The free end of the armature is normally spaced from the pole face so that a gap, diverging from the fixed end toward the free end of the armature, is defined between the armature and the pole face. An impact element is attached to the outer surface of the armature, adjacent the free end. In the absence of the energization of the pole piece, or other disturbing influences, the hammer is at an equilibrium or rest position between the paper impact position and the retracted position. Generation of a sufficient magnetic flux in the pole piece retracts the armature toward the pole face and causes the inner surface of the armature to progressively come into intimate contact with the pole face starting at the fixed end and progressing to the free end. In this manner, the armature stores mechanical energy and termination of the magnetic flux releases or fires the hammer, the impact element being thereby driven toward impact at the print station positioned forwardly of the rest position. The pole face preferably is coated with a thin layer of non-magnetic material, such as chromium, to increase the wear resistance of the pole face and provide, in effect, a non-magnetic gap that decreases remanence to reduce the release time of the hammer.

One of the advantages of this arrangement is that the hammer inherently compensates for differences in the thickness of the paper form. Since the paper is forward of the rest position of the hammer, the armature has released all of its stored energy and is in fact beginning to decelerate before impact. Since it must travel further forward to strike a thin medium (such as a single part form) than a relatively thick medium (such as a six part form), it has slowed more and impacts the thinner medium with less energy than it would the thicker medium. This is precisely the result that is desired.

Moreover, in the retracted position of the flexible armature, the initial air gap between the armature and the pole face is virtually eliminated, making it possible to retain the armature in this position with a holding current that is very small in comparison to the retract current. By retracting all previously fired hammers simultaneously, a relatively high speed, simple and economical magnetic retract system can be employed that minimized magnetic crosstalk problems. All hammer units receive the high energy retract flux simultaneously during the retract portion of the print cycle and this high energy flux is not present to cause crosstalk interference during the firing portion of the print cycle. Furthermore, precise timing is not necessary during the retract interval when the high energy flux condition exists.

A further feature of the invention permits a simple adjustment of the flight time (and relatedly the impact energy) to be made individually for each hammer unit. Once set, no further adjustment is required over extended periods of time.

In accordance with another aspect of the invention, "ghosting", that is, multiple impacts of the impact element, is prevented by a damping device including damping body having a small mass in relation to that of the hammer. The damping body is carried by a thin, cantilevered leaf spring and operatively associated with the hammer to collide at least twice with the hammer in opposite directions after rebound from the impact position. The damping body may be fabricated in its entirety of energy-absorbing damping material including a density additive to obtain the required mass, or may comprise a core of metal, for example, coated with damping material so that the collisions occur with a low coefficient of restitution thereby assuring the removal of sufficient energy from the hammer to preclude multi-impacting. The damping device is itself damped by a coating on the damping body leaf spring consisting of a damping material such as a flexible epoxy.

Pursuant to another feature of the invention, a means for inhibiting the travel of the hammer to prevent the impact element from reaching the impact position in the event of power loss is also provided. The inhibiting means is responsive to conditions signaling loss of power (such as might occur if the printer power supply is accidentally or otherwise disconnected) to immediately move an interposer member to a position at which it intercepts hammer travel. In this manner, the printing of an unwanted line is precluded whenever the magnetic flux generated in the hammer units collapses. In addition to being responsive to conditions indicating power loss, the interposer member may be actuated in response to failure conditions, such as ribbon breakage, necessitating the inhibition of hammer travel.

A paper clamping and tensioning means is also provided as a feature of the invention. The paper form is advanced intermittently on a line by line basis between print cycles. During each advancement of the paper the clamping means is biased lightly against the paper which is backed up by a resilient pad. The drag thereby introduced maintains the paper under uniform tension along substantially its entire width. During each print cycle, when it is desirable to "frame" or fix the position of the paper, the clamping means is displaced electromagnetically to firmly press the paper against the resilient pad.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be more clearly understood with reference to the accompanying detailed description taken in conjunction with the following drawings in which:

FIG. 1 is a block diagram of a typical printing system;

FIG. 2 is a simplified perspective view of a printing mechanism incorporating features of the invention;

FIG. 3 is a typical cross-section view, in elevation, of a portion of the printing mechanism of FIG. 2;

FIG. 4 is a front elevation view of a portion of the printing mechanism of FIGS. 2 and 3 with parts thereof in cross section taken along the plane 4—4 of FIG. 3;

FIG. 4A is a cross-section view of the hammer unit of FIG. 3 taken along the plane 4A—4A;

FIGS. 5A-5F are simplified elevation views of a portion of a hammer unit in accordance with the invention showing the sequence of operation thereof;

FIG. 6 is a graphic representation of hammer position as a function of time to further illustrate operation of hammer units pursuant to the invention;

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FIG. 7 is a graphic representation of hammer velocity as function of time to further illustrate operation of hammer units in accordance with the invention; and,

FIG. 8 is a graph of magnetic coil voltage versus time illustrating voltage changes in the course of releasing and retracting a hammer in accordance with the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, there is shown a typical line printing system in which the features of the present invention may be used. A hammer unit array or bank 10 includes hammer units that are selectively operable by hammer drive circuits 12 in timed relation with the movement of a character bank 14. The band 14 is looped about a pair of drums 16 and driven thereby at a relatively high constant velocity, for example, 170 inches per second (ips) past the hammer unit bank 10. Control circuits 18 containing the necessary signal storage and processing elements energize the hammer drive circuits 12 to control the print cycles in accordance with character and index timing signals and data received from an external data source. A print receiving medium, typically a paper web or form 20, is incrementally advanced between the hammer unit bank 10 and band 14 in a direction transverse to the direction of bank motion.

Although a line printing system of the kind employing a character band is shown, this should be considered as exemplary only. It will be evident that the features of the invention apply equally to systems employing other kinds of character or type carriers such as drums or chains.

FIG. 2 shows in somewhat simplified schematic manner a print mechanism 22 forming part of the printing system of FIG. 1 and illustrating further details thereof. The character band 14 and drums 16 are mounted on a platform 24 hingedly connected at one end to a housing 26. The platform 24 also carries a pair of motor driven ribbon spools 28 which alternately supply and take up an inked ribbon 30 in a manner well known in the art.

Referring now also to FIG. 3, the type carrying face of the character band 14 passes the ribbon 30 in close proximity while the other, smooth face of the band rides along a backing plate or anvil 32. The platform 24 also includes a surface 34 generally in alignment with the ribbon 30. An elongated, transversely extending resilient pad 36 is carried by the platform 24 and is recessed slightly in relation to the surface 34.

The housing 26 includes a base 38 and a fixed transverse frame 40. The housing further carries a paper feed mechanism shown in greatly simplified form as comprising a pair of sprockets 42 mounted on a shaft 44 and cooperating with spaced perforations along the edges of the paper form 20. A paper feed control 46 coupled to the shaft 44 causes rotation of the sprockets 42 in timed relation with the print cycle signals generated by the control circuits 18. The paper feed mechanism per se forms no part of the present invention and may comprise any of a number of conventional mechanisms which can control the movement of the paper past the print stations.

The hammer unit bank 10 is carried by the transverse frame 40 and may include as many individual hammer units 50 as print stations. For example, for a standard 132 column format (equivalent to 132 print stations) as many hammer units may be used; alternatively, fewer

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hammer units may be employed each unit servicing more than one print station. In the present arrangement, there are 66 hammer units 50, each servicing two print stations.

A hammer interposer and paper clamp assembly 52 disposed along the lower portion of the hammer unit bank 10 cooperates therewith the paper form 20 in a manner to be described. The assembly 52 is supported by pairs of flex pivots 54 coupled to the ends of assembly 52 and secured to the base 38.

After the paper form is loaded, the platform 24 is swung into position along the front margin of the housing so that the ribbon, the character band and the assembly 52 assume the operative relationships with respect to the hammer units 50 and the resilient pad 36 as shown in FIG. 3.

With reference now to FIGS. 3 and 4, each hammer unit 50 comprises generally a support 60, a magnetic pole piece 62, a hammer 64 and a hammer damper 66. The hammer unit 50 is connected to the frame 40 by a link 68 and appropriate screw fasteners.

The support 60 is fabricated of non-magnetic material so as to preclude shunting of the magnetic flux.

The pole piece 62 consists of a pair of spaced-apart, parallel plates 70 joined at their rear extremities by a bridging element 72 and bonded at their upper extremities to the non-magnetic support 60. The plates 70 have aligned front edges together defining a pole face 74. The pole face 74 has an outwardly curving, that is, convex configuration, the shape of the curvature thereof being described in greater detail below. The pole piece is preferably made of a magnetic material, such as a silicon-iron alloy, that reduces eddy currents to achieve rapid flux decay, and consequently, reduces hammer release time.

Further, the pole face preferably includes a thin coating of non-magnetic material to provide a small, non-magnetic gap that decreases remanence and hence reduces hammer release time. For example, the coating may comprise a layer of chromium 0.0002 to 0.0003 inch thick.

A field coil or winding 76 is wrapped about the bridging element 72 and has an electrical lead 78 extending from one end thereof. Lead 78 is connected to receive from appropriate circuitry, forming part of the hammer drive circuits 12, timed current pulses of the required durations and magnitudes for energizing the winding 76. The other end 78a of the winding 76 is grounded to the support 60.

The hammer 64 includes a leaf spring armature 80 of magnetic material mounted in cantilevered fashion in that one end is free and the other end is securely clamped between the link 68 and support 60. The armature 80, in its preferred form, may simply comprise a flat, rectangular strip fabricated of a magnetic spring steel alloy. The orientation of the curved pole face 74 relative to the armature 80 is such that the clamped end of the armature 80 is tangent to the upper end of the pole face. In the undeflected or rest position of the armature (as shown in FIG. 3) a gap exists between the armature and pole face that diverges gradually from the fixed end of the armature to the free end thereof.

The armature 80 has an inner face 82 in opposed relationship to the pole face 74 and an outer face 84. Attached by rivets or other suitable fastening means to the outer face 84 of the armature at the lower or free end thereof is an impact element or head 86. The impact 86 has upper and lower mounting flanges 88 and

90, respectively, connected to the armature 80. Projecting from the mounting flanges is an L-shaped structure defining at its outer end an upright portion or lip 92 having an outer planar surface 94 comprising the impact face of the hammer.

Referring momentarily to FIG. 5A, although some variation can exist, the preferred shape of the pole face 74 is such that a first or upper portion 96 thereof is a circular arc extending between the upper extremity of the pole face 74 and a point 98 along the pole face in approximate alignment with the upper edge of the flange 88 when the armature 80 is in the retracted position. The second or lower portion 99 of the pole face 74, extending from the point 98 to the lower extremity of the pole face, is straight (i.e., flat) and tangent to the arcuate portion 96 at the point 98. The part of the armature 80 that engages the arcuate portion 96 comprises the active length of the armature, storing mechanical energy when the hammer is retracted. This energy is used to fire the hammer, as will be further described below. In comparison to a pole face that is shaped to conform, for example, to the curvature assumed by a uniformly loaded cantilever beam (to which the armature might generally be analogized), the pole face shape of the present invention is not only more easily manufactured but provides a smaller air gap between the armature (at rest) and the pole face. Less energy and time is therefore required to retract the armature.

It should also be noted that the pole face 74 is longer than the armature 80, extending beyond the free end thereof. As a result, in its fully retracted position, the full length of the armature 80 is in intimate contact with the pole face 74 and the diverging air gap is essentially completely eliminated leaving only the small non-magnetic gap defined by the non-magnetic coating on the pole face 74, as discussed earlier. It will be readily appreciated by workers in the art that as a consequence, although a current pulse of relatively high magnitude is required in the winding 76 to retract the armature, only a very small current is then necessary to hold the armature in place against the pole face 74.

Besides the small holding current, another advantage of this arrangement is that upon generation of the required magnetic flux level, the armature, starting at the fixed end thereof, is drawn into progressive contact with the pole face to provide an action that eliminates wear which eventually affects flight time and the impact energy delivered at the print station.

The hammer damper 66 includes a small cylindrical damper body 100 coupled to the support 60 by a resilient element 102 preferably in the form of a thin, rectangular leaf spring. The body 100 includes small amounts of damping material 104 which may form front and rear projections of the body 100. Such damping material may comprise any substance with adequately lowers the coefficient of restitution of collision between the hammer damping body 100 and the impact head 86. For example, damping material 104 may be "Viton A", a synthetic rubber manufactured by E. I. duPont Company. Alternatively, the damper body may be fabricated in its entirety of resilient, energy-absorbing material that includes a density additive such as lead particles to obtain the required mass.

Damping of the damper body 100 to minimize its recovery time is enhanced by applying a coating 106 of a damping material to a surface of the damper leaf spring 102. Flexible epoxies of the conventional type such as

"Epoxy No. 2214" manufactured by Minnesota Mining and Manufacturing (3M Co.) are examples of materials that may be used for this purpose.

The upper or fixed end of the leaf spring 102 is clamped along with the armature 80 between the link 68 and the support 60. As best shown in FIG. 3, in the rest position of the hammer and hammer damper, the damper spring 102 curves outwardly toward its free end biasing the body 100 rearwardly against the upper flange 88 of the impact head 86. In contrast, the armature 80, having a significantly higher spring constant than the damper spring 102, remains substantially flat, that is, undeflected, while in the rest position.

It will be seen that the hammer unit of the invention is an essentially frictionless device with the pole face defining a positive, non-varying starting position. Thus, flight time and impact characteristics remain virtually constant for long periods, these parameters being functions only of leaf spring dimensions, elastic properties and mass. These are properties that can be precisely predicted and controlled and are not subject to variation through use. As a result, print registration is both consistent and accurate.

The flight time and consequently the impact energy which each hammer delivers at the impact position may be adjusted for each individual hammer unit 50 according to a further feature of the invention. An adjusting screw 110 extending through the frame 40 is threadedly received by the rear portion of the support 60. Referring to FIG. 3 specifically, adjustment of the screw 110 causes deflection of the link at approximately the point 112 and rotation of the hammer unit in the plane of the drawing. This moves the impact face 94 nearer to or further from the position of impact of the face 94 with the paper form 20. Although the link 68 is a solid steel element it can be deflected through the very small angles that are involved in making the adjustment without permanent deformation. Once the flight time of a particular hammer unit is adjusted no further adjustment is required irrespective of the thickness of the paper form. The extent of overtravel of the hammer past the rest position inherently compensates for such variations in thickness, the hammer having to travel further past the rest position for thinner forms thus having correspondingly decelerated. The impact energy is consequently inherently controlled by the hammer unit of the invention.

A damper pad 114 may be inserted between the frame 40 and the support 60 for absorbing any shocks generated by virtue of the operation of the hammer unit.

The operation of the hammer unit, described in conjunction with FIGS. 5A-5F, the solid line curve of FIG. 6, and FIG. 7, is as follows:

Upon energization of the winding 76 with a current pulse of predetermined duration and magnitude as will be described in greater detail below, the hammer moves rearwardly from the rest position 120 to the fully retracted position where it is held by a smaller current (FIG. 5A). In this position, which corresponds to $t = 0$ in FIGS. 6 and 7, the armature has stored mechanical energy. Damper body 100 remains in contact with the flange 88 of the impact head 86. Hammer firing occurs upon termination of the holding current, the hammer moving past the rest position 120 toward the impact position at the print station (FIG. 5B). The damper body 100 is still in contact with the flange 88 and moves in essentially the same arc as the head 86. Upon

impact, the face **94** squarely meets the paper form **20** pressing it and the ribbon **30** against the character band **14** (firmly backed up by the anvil **32**) thereby printing out the desired character. The inertia of the forwardly moving mass of the damper body **100** decouples it from the head **86** and carries it forward in free flight (FIG. 5C). An energy loss accompanies the print operation so that this process in itself assists the damping of hammer motion.

The inertia of the hammer having propelled the hammer past its rest position (which is the point of maximum velocity of the moving hammer), the hammer is decelerating as it strikes the paper. In FIG. 7 this is seen as a marked decrease in velocity. Immediately after the start of rebound of the hammer from the paper impact position the damper body **100**, still moving forward, collides with the lip **92** of the head **86** (FIG. 5D). Hammer energy is further reduced as a result of this first collision and is seen as a precipitous velocity loss in FIG. 7. The hammer continues rearwardly, reaches a maximum rearward excursion and begins its return towards the print station. The damper body, however, which continues to travel backwards, collides with the flange **88**. (FIG. 5E). This second collision, like the first, is at high relative velocity and results in a substantial energy loss as represented by the velocity drop in the graph of FIG. 7.

The hammer energy is now lowered to the point where its maximum forward excursion is less than the distance from the rest position to the print station or in other words (with reference to FIG. 5F) the distance *d* which is the closest the hammer now approaches the paper, is greater than zero. The result is that multiple impacts with the paper are precluded. Moreover, the hammer is quickly returned to substantially its initial rest position ready to be retracted for the next print cycle. Although two collisions between the hammer and hammer damper have been described, under particular sets of system parameters a third and even additional minor collisions may occur but in comparison to the first two the effects of these are relatively insignificant.

In connection with FIGS. 6 and 7, it should be noted that the values of displacement and velocity plotted along the ordinates are exemplary only and are not intended to limit or otherwise affect the scope of the claimed subject matter.

In FIG. 6, while the solid line plot shows the displacement vs. time of a hammer in accordance with the present invention, broken line plots marked "Path # 1" and "Path # 2" illustrate, respectively, the path the hammer would take if after the first collision there were no second collision and in the absence of any collisions. Since the slope of the curve represents hammer velocity, a comparison of the righthand extremities of the three plots of FIG. 6 shows that the velocity of the hammer in accordance with the invention has decayed substantially in comparison to the other two. In other words, in the absence of any damping or even with one collision between the damper body and the hammer, there is a good chance that the hammer will impact the paper more than once resulting in ghosting.

The following is a summary of the characteristics of one practical example of the invention:

Hammer unit overall width: 0.190 inch
Hammer head width: 0.190 inch
Armature width: 0.190 inch
Armature thickness: 0.030 inch
Armature unclamped length: 1.7 inches

Radius of curvature of arcuate portion **96** of pole face **74**: 10.5 inches

Effective impact, i.e., moving, mass: 1.0 g.

Hammer stroke: 0.095 inch

Print station coefficient of restitution (six part form): 0.45

Damping material (**104**) coefficient of restitution: 0.25

Damping spring width: 0.190 inch

Damping spring thickness: 0.004 inch

Damper moving mass: 0.15 g.

Damper stroke: 0.09 inch

Distance from rest position to impact position: 0.016 inch (six part form), 0.035 inch (single part form)

It will be seen that the mass of the damper body **100** is very small relative to the hammer mass. The damper system thereby introduces very little mass while it is coupled to the hammer during hammer flight. The coefficient of restitution of the damping material **104** is preferably low, that is, of the magnitude of about 0.2 but may be higher, for example 0.5, without adversely affecting performance.

It will also be appreciated that the total effective moving mass of the hammer unit is quite small, contributing to the minimization of contact time between the impact head and the paper.

With reference again to FIG. 3, the following is a description of a circuit means forming part of the drive circuits **12** for applying simultaneously to all of the hammer units **50** in the bank **10** a high level retract current to simultaneously retract all of the hammers that have been fired during a preceding part of the print cycle, and for providing a low level hold current.

The flux generating coil **76** is energized by a retract current generator **124** and a hold current generator **126**. The retract current generator **124**, which may comprise extremely simple circuitry, is in effect a switch that gates 1.5 amperes per hammer unit in response to a retract signal. This relatively high current induces a very high energy magnetic field in the pole piece **62**, drawing the armature **80** into contact with the face **74** of the pole piece **62** as previously described.

An isolation diode **128** decouples the retract current generator **124** from the hold current generator **126** and passes the 1.5 ampere retract current to lead **78** of the coil **76**. Similarly, isolation diodes **130** connected to the retract current generator **124** simultaneously pass the same retract current of 1.5 amperes to each of the remaining hammer units. A Zener diode **132** having a reverse breakdown voltage of approximately 35 volts has its cathode connected to ground and a blocking diode **134** is connected to conduct current in a forward direction from the anode of diode **132** to the anodes of the diodes **128** and **130**. As the low energy magnetic field rapidly collapses following termination of the hold current, a substantial negative voltage is induced in the lead **78**. Zener diode **132** clamps this voltage to approximately 35 volts, causing the energy of the magnetic field to be rapidly dissipated so long as the voltage of lead **78** exceeds -35 volts and thereby providing precise control of the time interval between termination of the hold current and the actual release of the hammer.

Hold current generator **126** passes a small holding current of approximately 150 ma through isolation diode **136** to the lead **78** of coil **76**. This current creates a small magnetic field which is sufficient to hold the hammer armature in the retracted position but which is not sufficient to cause retraction. The hold current is

generated in the absence of a release signal and terminated in the presence of a release signal. Unlike retraction, the firing times of each hammer are independent of the other hammers so that a separate hold current generator is required for each hammer unit in the hammer bank, each hold current generator being responsive to different release signals.

The release and retract signals may be generated in a conventional manner, the release signals being generated when a desired character arrives at a particular print station and the retract signal being generated at the termination of the firing portion of the print cycle.

The energization of the coil 76 is more fully explained with reference to FIG. 8 which indicates the voltage of lead 78 versus time during the course of a printing cycle. A time t_0 , the hammer of hammer unit 50 is held in a retracted position while coil 76 receives a current of about 150 ma from hold current generator 126 causing a resistive voltage drop 140 of about 3 volts. A time t_1 , which is dependent upon the synchronization of a desired character with the print station associated with hammer unit 50, a release pulse is received by holding current generator 126, causing termination of the holding current. The resulting rapid collapse of the magnetic field induces a negative voltage in the lead 78 which is clamped to -35 volts by Zener diode 132. During this clamping period the reverse current through Zener diode 132 causes rapid dissipation of the energy of the magnetic field. Once the induced voltage is reduced below -35 volts Zener diode 132 no longer conducts and the magnetic energy decays more slowly with the induced voltage following curve segment 142.

At time t_2 , the magnetic flux reduces to the point where the hammer actually separates from the pole piece and strikes the paper about 2 ms later. A voltage ripple 144 results from oscillations of the hammer following impact with the paper due to the small residual magnetism in the armature spring inducing an emf in the coil 76. Due to the particular hammer assembly construction which permits a constant hammer flight time over a long period of time by virtually eliminating wear and positional changes, and the precise control of actual release time t_2 provided by Zener diode 132, the time $t_3 - t_1$ between receipt of a release command and printing impact can be precisely and invariantly predicted. In the present arrangement there is an interval of approximately 2 ms between receipt of a release command at t_1 , and a printing impact at t_3 . At some time t_4 , which is subsequent to the actual release time t_2 , the release pulse is terminated and the holding current is resumed. The hammer, of course, remains in the rest position between the impact and retract positions.

At some time t_6 following termination of a firing portion of a print cycle, a retract command is received which activates the retract current generator 124. Although any conventional source of current is sufficient, the retract current is advantageously provided by a single half cycle 146 of a full wave rectified voltage source having a peak voltage of about 30 volts. By synchronizing the retract pulse with the voltage half cycle 146 excessive power dissipation is eliminated while insuring adequate energy for retract. In particular, the retract pulse begins at t_6 at a phase angle $\theta = 45^\circ$ following a zero point at t_5 and terminates at a timer t_7 which coincides with the next zero point of the half cycle 146. Initiation of the retract command prior to time t_6 would merely cause more power to be dissipated as heat in the

coils of the hammer units without improving the retract operation. During damper recovery time interval t_7 to t_8 of 1 or 2 ms, oscillations of the damper 66 decay and at time t_8 a new print cycle may begin.

It will be appreciated that other arrangements may be employed to generate the retract current. It is only necessary that about 1.5 amperes per hammer unit be provided for a sufficient length of time to insure retraction of all hammers.

The interposer and clamp assembly 52 includes an upright interposer plate 164 having an upper margin defining an abutment 166 coated with an energy-absorbing material 167 facing the lower flanges 90 of all of the impact heads 86 in the hammer unit bank 10. Projecting forwardly from the lower edge of the interposer plate is a transverse clamp bar 168 extending substantially the entire width of the paper form 20 and positioned for cooperation with the resilient pad 36. The mass of the interposer/clamp bar assembly 52 substantially greater, for example, by a factor of four times, than the total effective moving mass of the hammers. The flex pivots 54 carrying the assembly 52 are in the form of leaf springs normally biasing the assembly 52 forwardly so that the paper form is pressed lightly against the pad 36 by the bar 168. This introduces a small amount of drag as the form 20 is advanced upwardly by the feed sprockets 42 and tensions the paper uniformly.

A horizontal shaft 170 is attached to the rear end of the assembly 52 and extends through openings in a clamp solenoid 172 and interposer solenoid 174.

A magnetic disc 176 secured to the shaft 170 between the solenoids 172 and 174 functions as an armature common to both solenoids.

Energization of the clamp solenoid 172 is controlled by a clamp solenoid command circuit 178 which in turn is responsive to timed clamp signals generated by the control circuits 18.

With both solenoids 172 and 174 deenergized, the disc armature 176 assumes approximately the position shown in FIG. 3 adjacent the clamp solenoid but spaced therefrom by a small gap 182. The size of the gap 182 has been exaggerated in the drawing for clarity; actually, such gap will typically be no greater than about 0.010 inch. Just prior to a print cycle, clamp solenoid 172 is energized thereby drawing the disc 176 toward the solenoid 172. The clamp bar 168 is thereby advanced until the paper form is clamped firmly between the bar 168 and the resilient pad 36 thereby fixing or framing the form 20 for printing. At the end of the print cycle, solenoid 172 is deenergized and the assembly 52 and disc 176 return to their initial equilibrium position shown in FIG. 3.

The interposer solenoid 174 is energized through a switch 186 by an electrical energy storage device 188 which, in a preferred form of the invention, may be a capacitor charged by rectified current from the printer power supply. Alternatively, storage device 188 may be a battery. Switch 186 is closed in response to signals received from a number of sensors, including sensors 190, 192 and 194 thereby establishing a current path between the storage device 188 and the solenoid 174. Sensor 190, for example, monitors line voltage which, upon dropping below a predetermined level, closes switch 186 to cause energization of the solenoid 174. Other sensors, such as 192 and 194, may be included to detect any of a variety of other failure or error conditions, such as ribbon breakage and loss of the hold cur-

rent power supply, requiring the hammers to be kept from reaching the paper impact position.

In the event power to the printer is shut off, disconnected or otherwise lost, the interposer solenoid 134 is energized attracting the disc 140 and moving the assembly 52 rearwardly to the position shown by the broken lines. It will be evident that although in the normal tensioning or clamping positions of the assembly 52 the abutment in no way interferes with or inhibits the travel of the hammers, in the interposing position the abutment 126 intercepts the arc of travel of the hammers and because of the substantially greater mass of the interposer/clamp bar assembly, prevents the hammers from reaching the print stations.

Although the interposer and paper clamping functions are shown integrated into a single structure, since these functions are separable, they may be performed by independent structures.

What is claimed is:

1. In a high speed line printing apparatus for printing on a print-receiving medium such as a paper form, said apparatus including a print mechanism comprising hammer means selectively operable during print cycles in timed relation with a movable character carrier to make printing impact with said paper form and means for advancing said paper form in a feed direction incrementally past said print mechanism, said hammer means having a printing impact position and a retracted position away from said printing impact position, said paper form being advanced between successive timed print cycles, the character carrier being of the type which moves transverse to the feed direction of the paper form, the combination comprising:

- means for tensioning and clamping the paper form including:
 - i. a bar extending substantially the entire width of said paper form and positioned to ride in contact with said form;
 - ii. a resilient backstop disposed opposite said bar;
 - iii. means coupled to said bar for continuously biasing said paper form against said resilient backstop to maintain said paper form under tension during advancement thereof; and
 - iv. means responsive to said timed print cycles for displacing said bar toward said backstop to firmly clamp said paper form between said bar and said backstop during each of said timed print cycles;
- said print mechanism being disposed between said advancing means and said tensioning and clamping means along the feed direction of said paper form;
- means for sensing at least one error condition requiring inhibition of said hammer means to prevent said hammer means from reaching said printing impact position, said sensing means producing a signal indicative of the presence of said error condition;
- an interposer member integral with said bar, said interposer member having an inhibiting position in which said member is disposed to engage said hammer means and prevent said hammer means from reaching said printing impact position and a non-inhibiting position in which said hammer means is free to move to said printing impact position, said member being biased to said non-inhibiting position by said biasing means, the mass of said interposer and bar being substantially greater than the movable mass of said hammer means; and
- means coupled to said error sensing means and connected to said interposer member and bar for dis-

placing said member to said inhibiting position in response to said error-indicating signal.

2. In a high speed line printing apparatus for printing on a print-receiving medium such as a paper form having a given width, said apparatus including a movable character carrier, a print mechanism comprising a bank of hammer means, and means for incrementally advancing said paper form in a feed direction passing between said movable character carrier and said print mechanism, said hammer means having a printing impact position and a retracted position away from said printing impact position and being selectively operable during print cycles in timed relation with said character carrier to make printing impact with said paper form along a print line transverse to said feed direction, said paper form being advanced between successive print cycles, the combination comprising:

- a resilient backing member extending across the width of said paper form on the side opposite said print line and parallel thereto;

- an interposer and clamp assembly disposed adjacent the print line, said assembly including:

- e. a paper form clamp bar extending across the width of said paper form in confronting relationship with said resilient backing member;
- ii. an interposer plate secured to said clamp bar and having a surface extending along said bank of hammer means and immediately adjacent thereto; and

- iii. means for supporting said assembly for movement toward and away from said paper form, said supporting means biasing said assembly toward a first operative position in which said clamp bar is adapted to lightly press said paper form against said resilient backing member to tension said paper form during advancement thereof;

- means for generating a clamp signal during the portion of each print cycle that printing impact takes place;

- actuator means responsive to said clamp signal and connected to said assembly for moving said assembly to a second operative position in which said clamp bar firmly clamps said paper form against said resilient backing member during said portion of said print cycle; and

- means for generating a hammer means inhibit signal, said actuating means being coupled to said inhibit signal generating means to be responsive thereto to move said assembly to a third operative position in which said interposer plate surface is disposed to engage said hammer means to prevent said hammer means from reaching said printing impact position.

3. The combination, as defined in claim 2, in which said means for generating said hammer means inhibit signal includes:

- normally open switch means connected to said actuator means;

- means for sensing at least one error condition requiring inhibition of said hammer means, said sensing means being coupled to control said switching means; and

- energy storage means coupled to said switch means, the presence of said error condition closing said switch means to connect said energy storage means to said actuator means to move said assembly to said third operative position.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,919,936
DATED : November 18, 1975
INVENTOR(S) : Gordon Brent Barrus et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 48, "acieve" should read --achieve--;
line 56, "srping" should read --spring--; line 63, after
"velocity," and before "minute", "and" should read --any--;
line 68, "natrually" should read --naturally--. Column 2,
line 1, "lubircant" should read --lubricant--; line 27,
after "with" and before "liquid,", "said" should read
--sand--; line 41, "tha" should read --that--. Column 3,
line 4, after "invention," and before "is" insert --there--;
line 7, "maagnetic" should read --magnetic--; line 10,
"relaltionship" should read --relationship--; line 56,
"minimized" should read --minimizes--. Column 5, line 28,
"bank" should read --band--; line 40, "plateform" should
read --platform--. Column 6, line 7, after "therewith" and
"the" insert --and with--. Column 7, line 56, "with"
should read --that--. Column 8, line 20, "Theses" should
read --These--. Column 13, line 6, before "52", "sembllly"
should read --sembly--. Column 14, line 23, before "a
paper form", "e." should read --i.--.

Signed and Sealed this

sixteenth Day of March 1976

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks