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Barrus et al.

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[45] **Sept. 16, 1975**

[54] **HIGH SPEED LINE PRINTING APPARATUS**

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[73] Assignee: **Pertec Corporation,** El Segundo, Calif.

[22] Filed: **Jan. 23, 1974**

[21] Appl. No.: **435,759**

Related U.S. Application Data

[62] Division of Ser. No. 333,221, Feb. 16, 1973, Pat. No. 3,834,303.

[52] **U.S. Cl.** **101/93.48;** 101/322

[51] **Int. Cl.²** **B41J 9/02**

[58] **Field of Search** ..... 101/93 C, 96, 299, 306, 101/317, 322; 197/47, 107, 187

[56] **References Cited**

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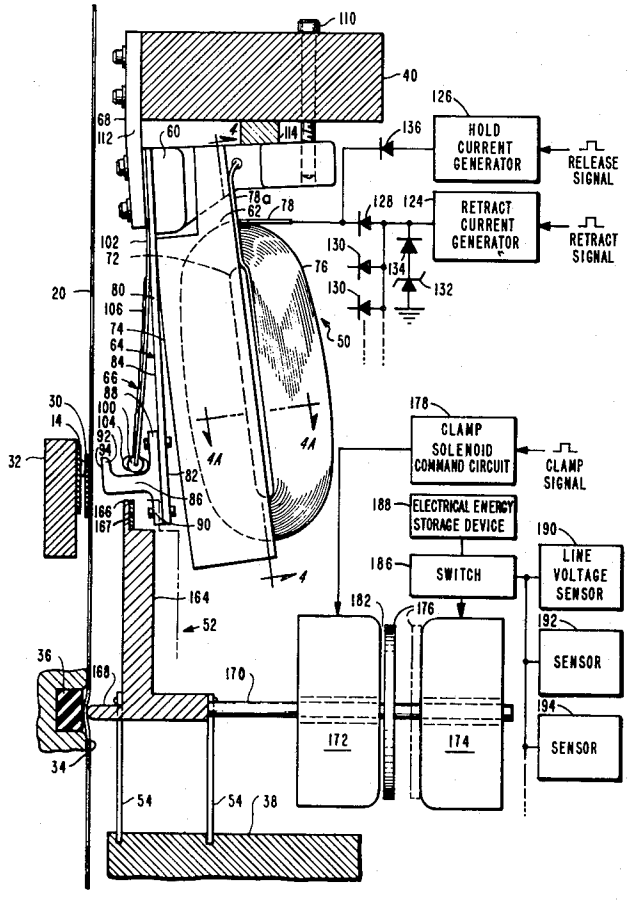
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Primary Examiner—Edgar S. Burr
Assistant Examiner—Edward M. Coven
Attorney, Agent, or Firm—Fraser and Bogucki

[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 inhibitng the flight of the hammers in the event of an error condition such as a power failure.

4 Claims, 14 Drawing Figures



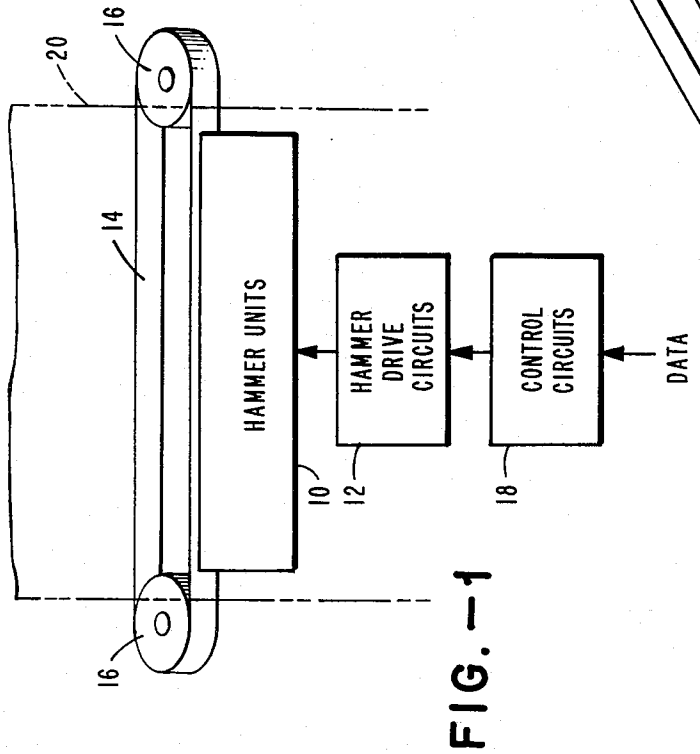
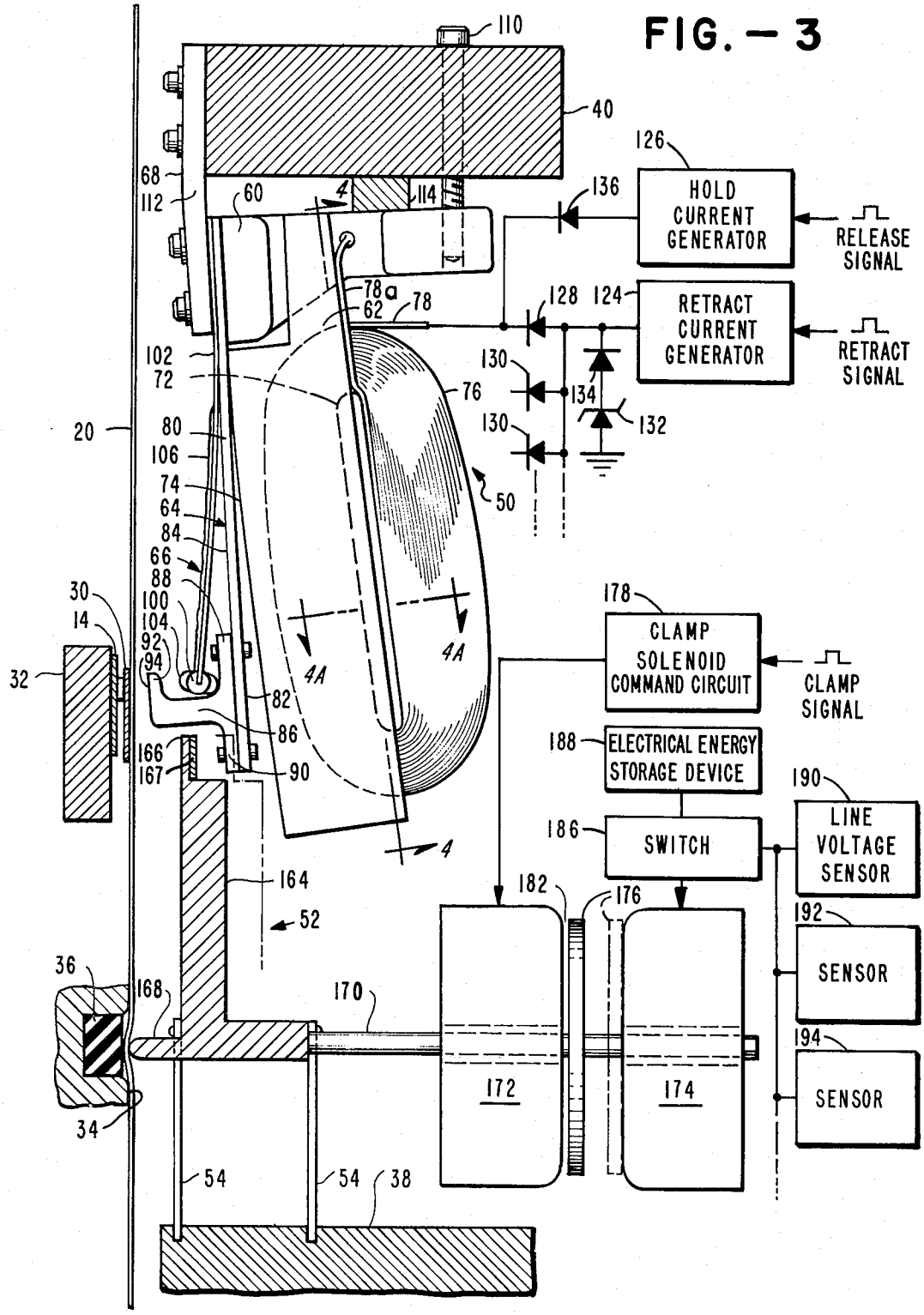

20
16
14
HAMMER UNITS
10
HAMMER DRIVE CIRCUITS
12
CONTROL CIRCUITS
18
DATA
16

FIG. -1

PAPER FEED CONTROL
46
26
42
50
50
54
38
52
44
40
42
20
10
54
28
22
16
30
36
34
32
14
16
28
24

FIG. -2

FIG. — 3


110
40
126
HOLD CURRENT GENERATOR
136
RELEASE SIGNAL
68
112
60
4
114
78a
78
62
128
124
RETRACT CURRENT GENERATOR
RETRACT SIGNAL
102
72
130
134
132
76
20
80
106
74
64
84
66
88
100
104
92
94
50
30
14
32
178
CLAMP SOLENOID COMMAND CIRCUIT
CLAMP SIGNAL
4A
82
86
90
166
167
188
ELECTRICAL ENERGY STORAGE DEVICE
190
LINE VOLTAGE SENSOR
186
SWITCH
164
52
182
176
36
168
170
192
SENSOR
194
SENSOR
172
174
34
54
54
38

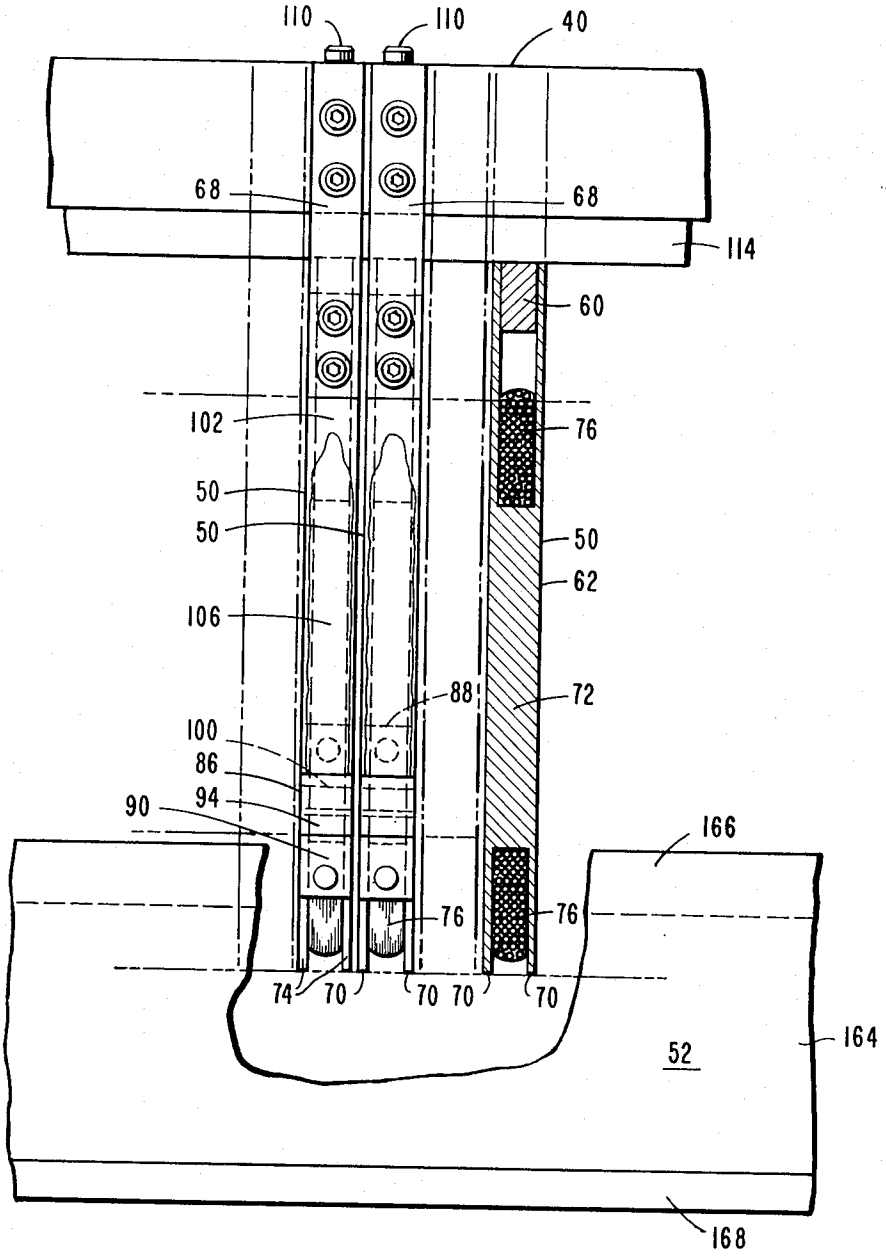

110
110
40
68
68
114
60
102
76
50
50
50
62
106
88
72
100
86
94
90
166
76
76
74
70
70
70
70
164
52
168

FIG. — 4

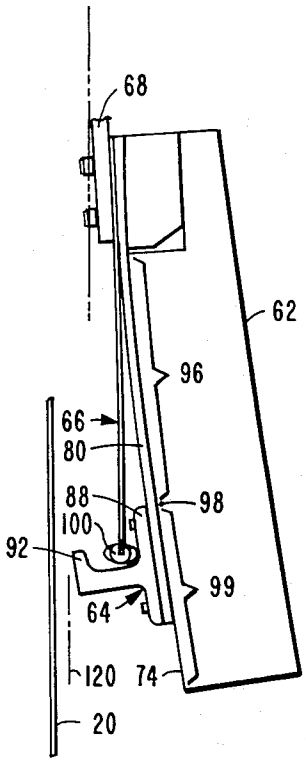


FIG. — 5A

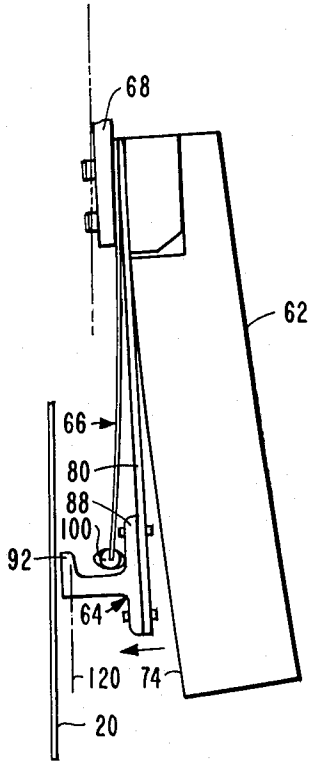


FIG. — 5B

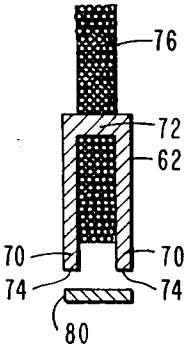


FIG. — 4A

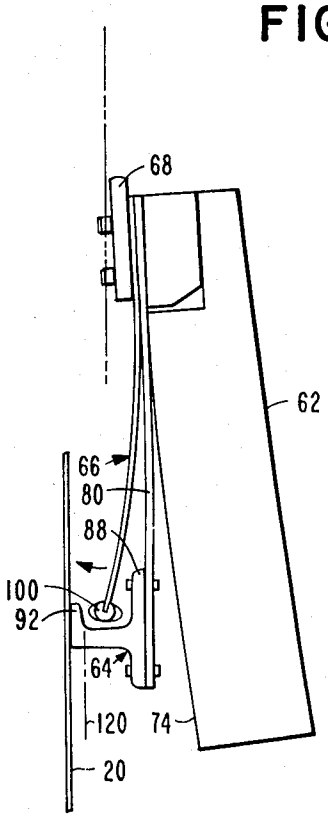


FIG. — 5C

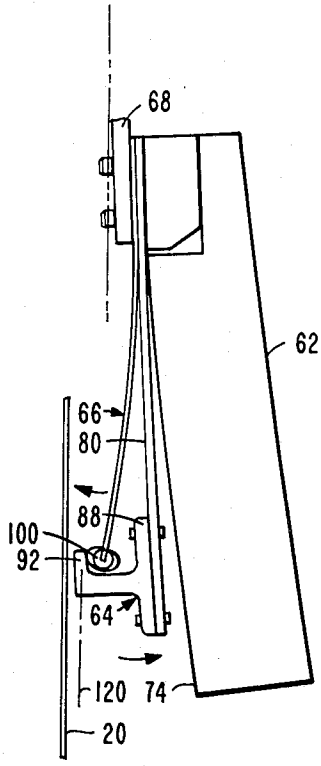


FIG. — 5D

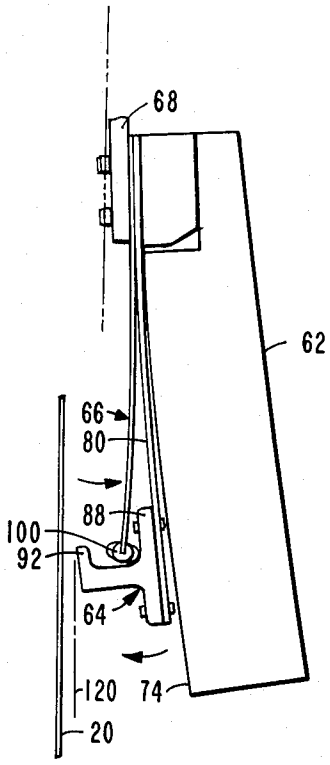


FIG. — 5E

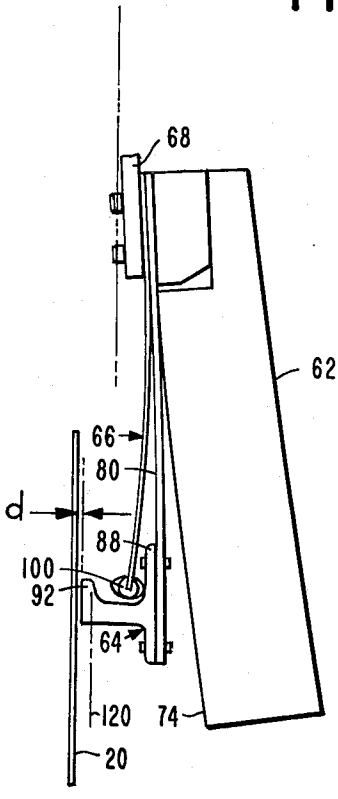


FIG. — 5F

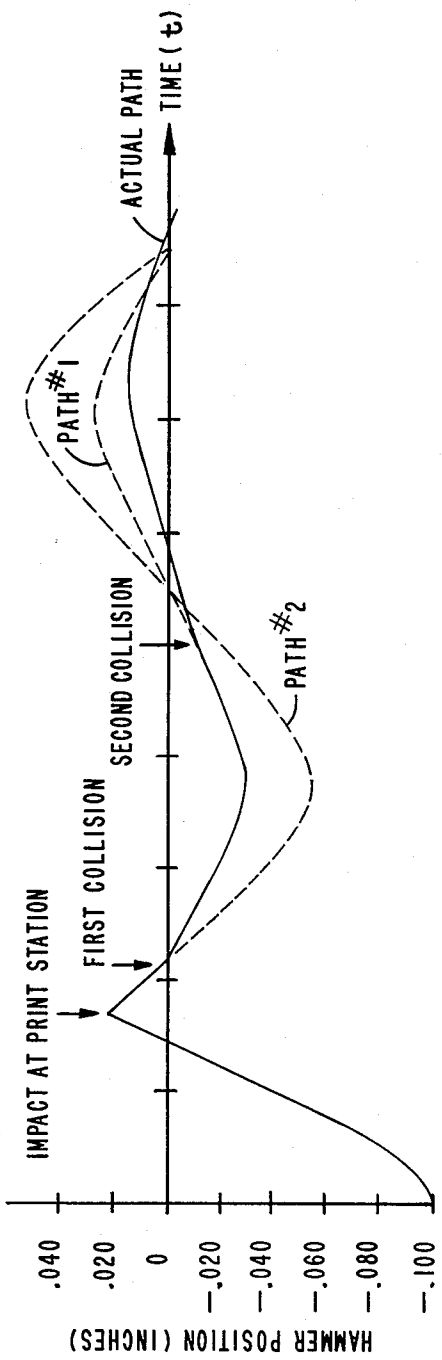

HAMMER POSITION (INCHES)
.040
.020
0
-.020
-.040
-.060
-.080
-.100
IMPACT AT PRINT STATION
FIRST COLLISION
SECOND COLLISION
ACTUAL PATH
PATH #1
PATH #2
TIME (t)

FIG.—6

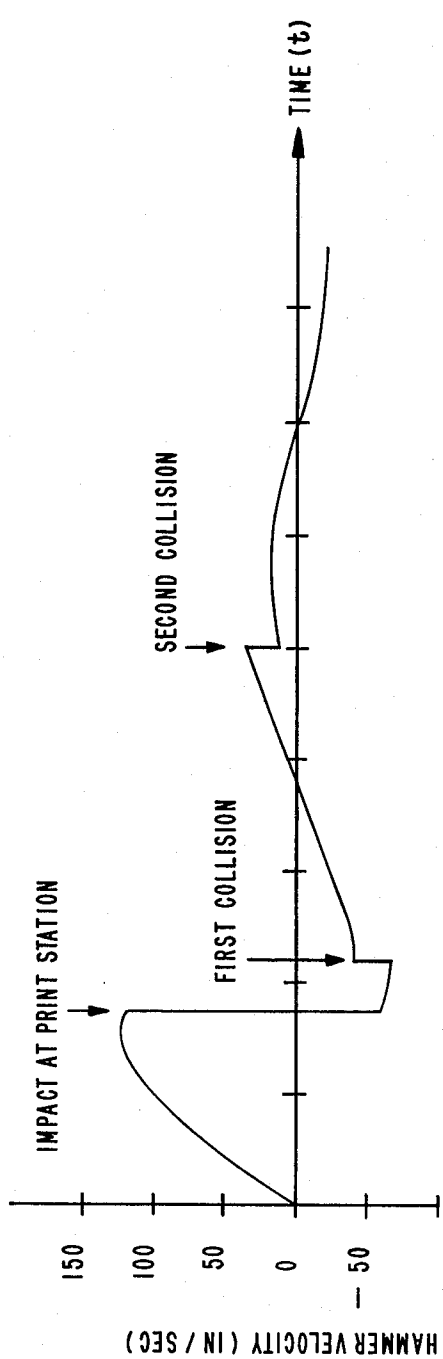

HAMMER VELOCITY (IN / SEC)
150
100
50
0
-50
IMPACT AT PRINT STATION
FIRST COLLISION
SECOND COLLISION
TIME (t)

FIG.—7

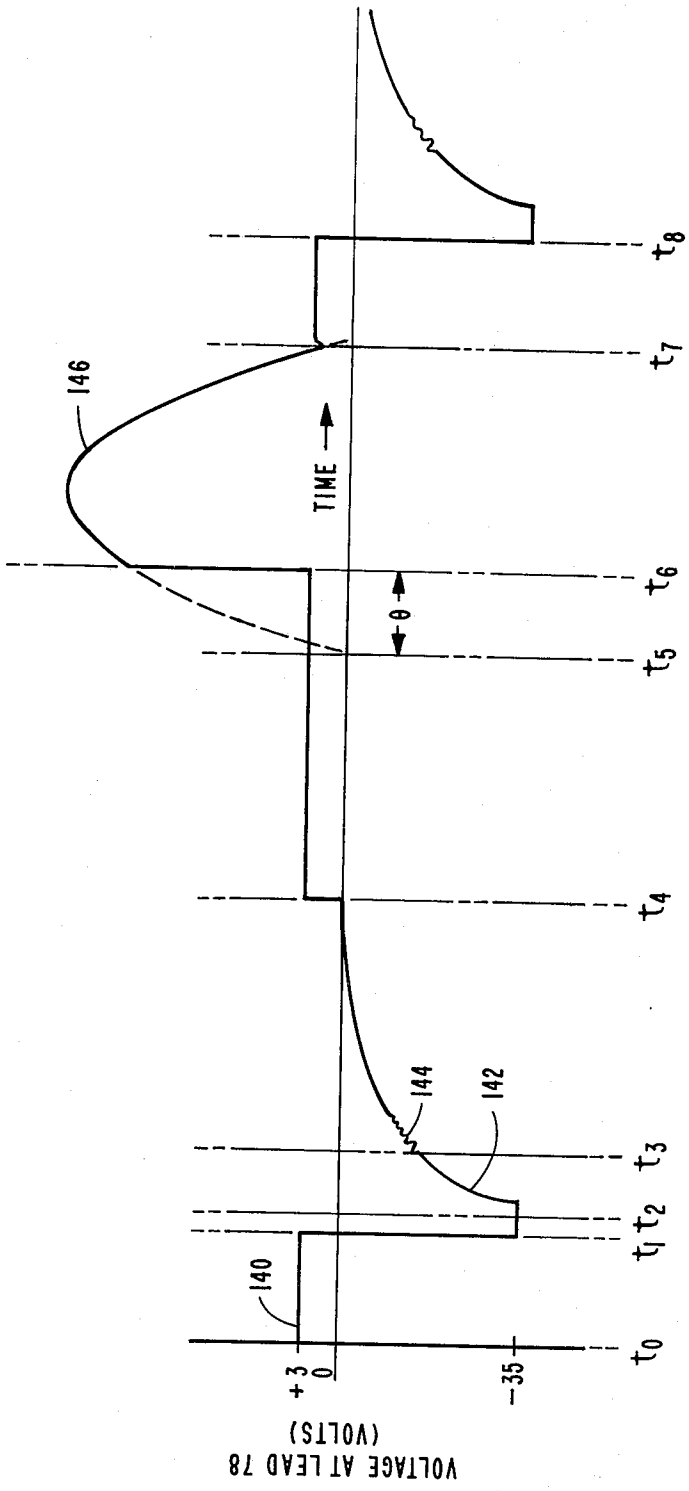

VOLTAGE AT LEAD 78
(VOLTS)
+3
0
-35
140
144
142
146
TIME
θ
t_0
t_1
t_2
t_3
t_4
t_5
t_6
t_7
t_8

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 critcial 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 ot 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 consistant 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, any 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 somtimes 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 sand, 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 heretofore prevented optimum combinations of 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, there is provided a pole piece having a convex pole face and a 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 porgressively 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 minimizes 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 wtih 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 in 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;

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 band **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 band 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 mechanismm **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 alternatively 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** alos 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 nno 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 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 and with 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 a 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 picce 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 **78***a* 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 head **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** inlcudes 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 that 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," as 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 No. **1**" and "Path No. **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 (**6** 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 (**6** 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. At 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. At time t_1, which is dependent upon the synchronication 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 $\theta = 45°$ following a zero point at t_5 and terminates at a time 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** is 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 current 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. A hammer arrangement for use in a high speed printer comprising:

means for generating a magnetic flux during selected time periods;

hammer means positioned adjacent said flux generating means for magnetic coupling therewith, said hammer means including impact means and spring means, said spring means having an end fixed in relation to said magnetic flux generating means and a free end supporting said impact means, said impact means having a retracted position and a printing impact position, said impact means being biased by said spring means away from said retracted position and toward a rest position between said retracted and printing impact positions, generation of said magnetic flux retracting said impact means to said retracted position and storing energy in said spring means, said spring means driving said impact means toward said impact position upon termination of said magnetic flux;

means for sensing a power failure error condition which requires inhibition of the flight of said impact means to prevent said impact means from reaching said printing impact position, said sensing means producing a signal indicative of the pressure of said power failure;

means responsive to said sensing means signal for engaging said hammer means and inhibiting the flight of said impact means to prevent said impact means from reaching said printing impact position; and

means including energy storage means responsive to said sensing means signal and coupled to actuate said means for engaging said hammer means to inhibit flight of said impact means.

2. A hammer arrangement, as defined in claim **1,** in which:

said inhibiting means includes an interposer member having an inhibiting position and a non-inhibiting position, said interposer member having an energy-absorbing surface adapted to be engaged by said hammer means in the inhibiting position of said interposer member, the mass of said interposer member being substantially greater than the mass of said hammer means;

and which includes:

means for biasing said interposer member toward said non-inhibiting position; and

means coupled to said error condition sensing means and connected to said interposer member for displacing said member to the inhibiting position in response to the presence of said error indicative signal.

3. A hammer arrangement, as defined in claim **2,** in which:

said displacing means includes a solenoid device and an electrical energy storage device connected to said solenoid device through switch means operable to be closed by said error indicative signal, said biasing means comprising leaf spring elements carrying said interposer member.

4. A hammer arrangement, as defined in claim **1,** which includes:

means for sensing at least one error condition additional to said power failure error condition, which additional error conditon requires inhibition of the flight of said impact means to prevent said impact means from reaching said printing impact position, said additional error condition sensing means producing a signal indicative of the presence of said additional error condition, said hammer means engaging and inhibiting means being coupled and responsive to said additional error condition sensing means.

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