March 9, 1965 C. J. HELMS 3,172,353

VARIABLE FORCE HAMMER HIGH SPEED PRINTER

Filed June 17, 1963 2 Sheets-Sheet 1

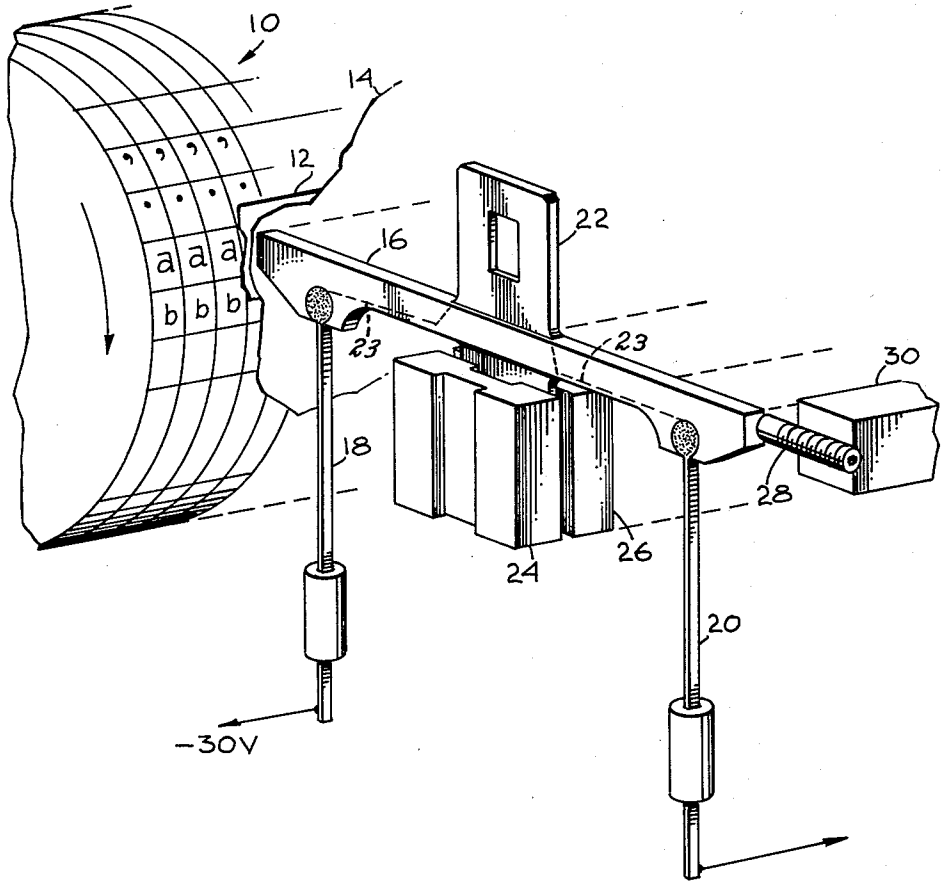


Fig. 1

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VARIABLE FORCE HAMMER HIGH SPEED PRINTER

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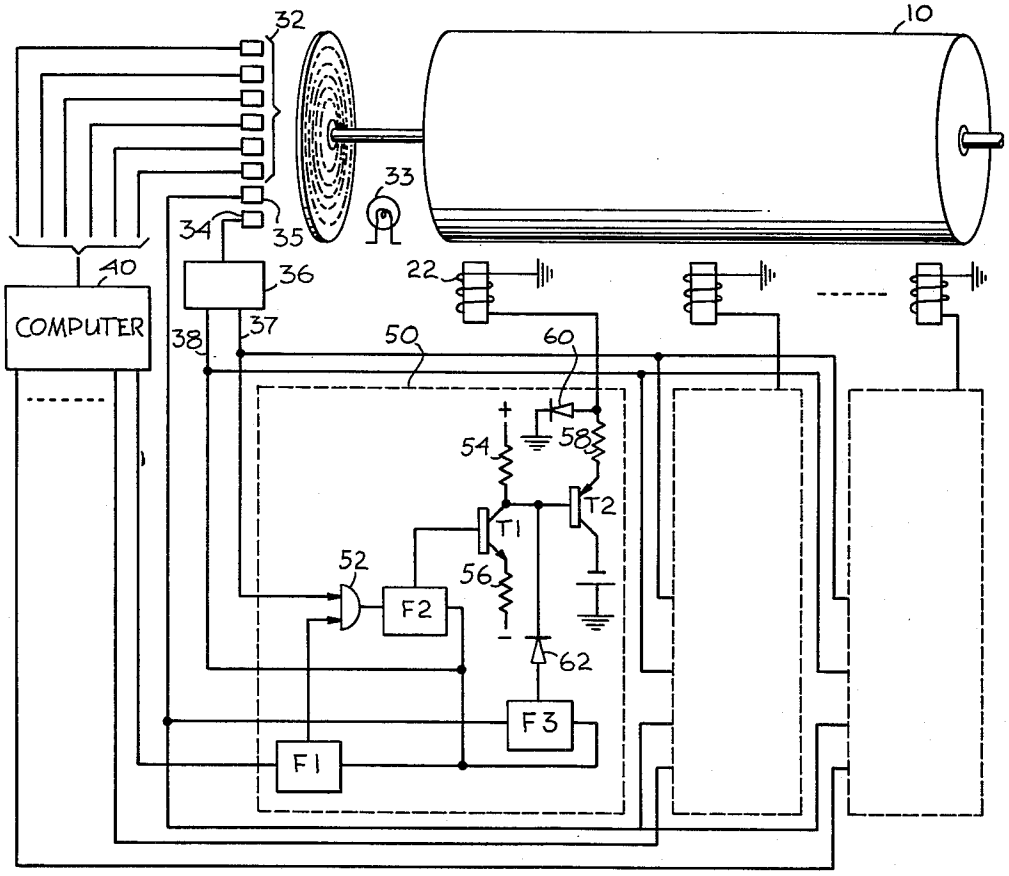


Fig. 2

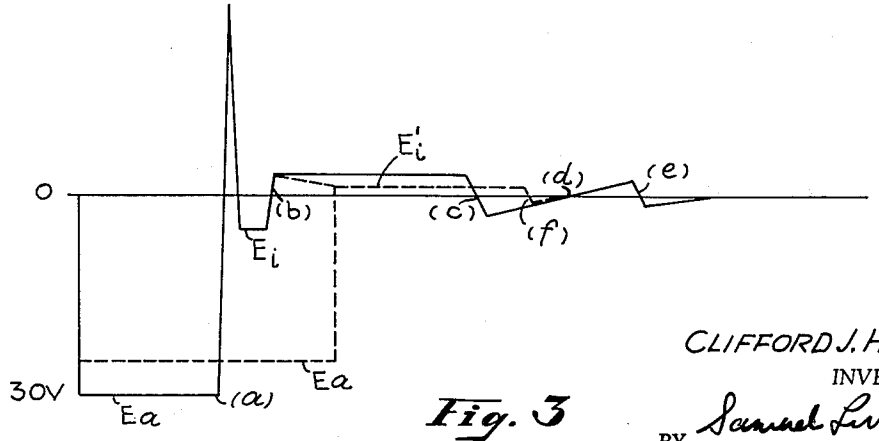


Fig. 3

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United States Patent Office 3,172,353
Patented Mar. 9, 1965

3,172,353
VARIABLE FORCE HAMMER HIGH SPEED PRINTER

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Filed June 17, 1963, Ser. No. 288,303
9 Claims. (Cl. 101—93)

This invention relates generally to high speed printers and more particularly to means for controlling the operation of hammers utilized in such printers.

Most high speed printers make use of a set of hammer assemblies including aligned hammers positioned adjacent a movable printing surface, such as a rotatable drum. The drum surface is provided with peripheral tracks, each track including a set of raised printing characters. A printing ribbon is positioned between the drum surface and the aligned hammers and a paper strip is adapted to be moved between the ribbon and the hammers. Printing is accomplished by incrementally moving the paper strip, line by line, and by selectively actuating each hammer at an appropriate time to thereby propel the hammer against the paper urging the paper against the ribbon and drum, when the desired character on the drum moves into alignment with the hammer.

Although the performance of printers of this type has in general been highly satisfactory, certain significant undesirable aspects have become apparent. One of these aspects is the need for frequent adjustment of the hammer assemblies. Since it is of course highly desirable that the characters printed on the paper be in alignment, it is necessary that each hammer strike the paper when the characters on the drum are in the same relative position. Assuming proper orientation of the characters on the drum, this can be accomplished by maintaining constant the travel time of each hammer, that is the time between actuation of the hammer and engagement of the hammer with the drum. In order to maintain the travel time constant, the travel distance of the hammer should remain constant over extended periods of use. Consequently, each hammer assembly generally includes an adjustable positioning backstop adapted to engage the hammer to enable its rest position to be precisely established. Because of wear however, resulting from the repeated collisions between the hammer and the backstop subsequent to the hammer bouncing back from urging the paper and ribbon against the drum surface, frequent readjustment of the backstop is necessary.

A further undesirable aspect of most known printers of the type described involves the consistency of the printing intensity from character to character. Because the hammers are generally propelled against the drum with the same force regardless of the characters being printed and because of the differences in area of different characters (e.g. contrast the small area of the character "." with the relatively large area of the high density character "w"), the resulting printing generally consists of characters having different intensities. An associated problem involves drum wear. That is, drum wear after long periods of use is most noticeable on low area characters which are usually subjected to the greatest impact force per unit area.

In U.S. patent application Serial No. 279,710 filed on May 13, 1963 by Clifford J. Helms and entitled "Printing Hammer Assembly," an improved hammer assembly is disclosed in which a coil is carried by a hammer which in turn is mounted on flexible support members. The support members are conductive and are connected to the coil terminals. The coil is disposed in a permanent magnetic field which interacts with a magnetic field generated by driving a current through the coil to thereby cause the hammer to be propelled against the printing drum. As a consequence of this type of construction, access to the coil terminals is continually available. By applying appropriate signals to those terminals, continuous control can be exercised over the movement of the hammer which could thereby enable the above recited undesirable aspects of the prior art to be obviated.

Therefore, it is an object of the present invention to provide an improved printing hammer assembly which is more reliable and which produces a better printed product than heretofore known assemblies.

More particularly, it is an object of this invention to provide means in a hammer assembly for braking the hammer movement to thereby reduce backstop wear and consequently increase the reliability and reduce the amount of required maintenance.

It is a further object of this invention to provide means in a hammer assembly for braking the hammer movement to thereby reduce the recovery time; that is the time which must be allowed between successive actuations of the hammer.

It is a further object of this invention to provide means in a hammer assembly for controlling the printing intensity and for reducing drum wear.

Briefly, the invention herein is directed to a hammer assembly in which braking and printing intensity control can be exercised over the hammer thereof by the application of appropriate electrical signals to a magnetic field producing means carried by the hammer.

In a preferred embodiment of the invention, a hammer assembly including a movable hammer carrying a coil is provided. The coil is disposed in a permanent magnetic field such that a current initiated in the coil generates a magnetic field which interacts with the permanent magnetic field to thereby propel the hammer in a first direction causing it to strike a printing drum. Inasmuch as friction forces are reduced to a minimum to permit extremely fast action by the hammer, the hammer normally rebounds from the drum and strikes the backstop with close to half the energy initially imparted to it by the interacting magnetic fields. By dissipating a significant portion of the hammer energy prior to its engagement with the backstop, backstop wear and recovery time is considerably reduced. Dissipation of the hammer energy is effected by maintaining the current in the coil subsequent to the hammer striking the drum whereby the interacting magnetic fields will tend to continue to urge the hammer in the first direction thereby resisting the rebound motion and effectively dissipating a portion of the hammer energy.

In order to control printing intensity, a reduced amount of energy can be imparted to the hammers when they are to strike low area characters such as ".", ",", etc. The energy can be reduced by reducing the amplitude of the current driven through the coil. Of course however a reduction in current reduces the propelling force on the hammer thereby increasing its travel time. However, this increase in travel time can be compensated for by shifting the position of the low density characters on the drum. For example, the "." which should be printed on the bottom of the line can be positioned at the top of a character position on the drum. The displacement of the low area character is compensated for by the extended travel time of the hammer resulting in the printing of the low area character in the proper position on the paper strip with the proper intensity. By reducing the force with which the hammer strikes low area drum characters, drum wear is reduced and the drum life is extended.

The novel features that are considered characteristic of this invention are set forth with particularity in the

appended claims. The invention itself both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawings, in which:

FIGURE 1 is a perspective view of a portion of a high speed printer illustrating the relationship between the hammer assemblies and printing drum;

FIGURE 2 is a schematic diagram illustrating the circuit means for exercising braking and printing intensity control over the printing hammers; and

FIGURE 3 is a waveform chart illustrating the voltages applied to and induced in the hammer coil.

Attention is now called to FIGURE 1 of the drawing which illustrates a portion of a high speed printer. The printer includes a printing drum **10** whose peripheral surface is divided into a plurality of peripheral tracks. An identical set of raised printing characters is disposed in each of the tracks with corresponding characters being in alignment. The drum **10** is adapted to rotate in the direction of the arrow.

Positioned immediately adjacent the surface of the drum **10** is a printing ribbon **12**. The front face of a paper strip **14** is positioned adjacent the ribbon **12**. Adjacent the rear surface of the paper strip **14** are a plurality of printing hammer assemblies, each assembly including a printing hammer **16**.

Each hammer **16** (as disclosed in the aforecited patent application Serial No. 279,710) is supported on spaced conductive, resilient, and flexible support members **18** and **20**. A coil **22**, whose terminals **23** are respectively connected to the support members **18** and **20**, is carried by each of the hammers **16**. The coil **22** is received between a pair of spaced permanent magnets **24** and **26**. Physically opposed poles on the magnets **24** and **26** are of opposite magnetic polarities and as a consequence, when a current is initiated in the coil **22** in a first direction, the coil will tend to position itself between one set of physically opposed poles, and when a current is driven through the coil in an opposite direction, the coil will tend to position itself between a second set of physically opposed poles. Consequently, by energizing the coil at an appropriate time in an appropriate direction, the hammer **16** can be propelled against the paper **14** to urge the paper and ribbon against a selected character on the drum. In this manner, an impression of that character is printed on the front face of the paper **14**. Inasmuch as a plurality of drum tracks are provided and a hammer is associated with each drum track, a full line can be printed during each rotation of the drum **10**. Of course, the paper **14** should be incrementally moved between successive drum rotations.

In order to assure proper alignment of the printing on the paper **14**, it is essential that the hammers **16** strike the drum when the characters thereon are in the same relative position. This can be accomplished by properly orienting the characters on the drum and maintaining the hammer travel times constant. The travel time is the interval between which the coil carried by the hammer is energized and the time at which it strikes the drum. In addition to it being desirable that the travel times be consistent for all the hammers, the various travel times should not vary over a period of extended use.

Assuming that the members **18** and **20** are sufficiently flexible so that their effect on the hammer movement is negligible, the travel time (t_t) of each hammer is represented by the following relationship:

$$t_t = \sqrt{\frac{2mx}{BlI}}$$

where

m represents the mass of the hammer and coil.
x represents the distance the hammer must travel from a rest position to the drum.

B represents the average magnetic flux density established by the permanent magnets.
l represents the effective length of the coil conductor; and
I represents the current in the coil.

The expression BlI determines the force applied to the hammer serving to propel it against the drum. Since the mass, the flux density, and the conductor length are all constants and since the current can be precisely controlled, the travel time will remain constant if the travel distance x remains constant. In order to establish a constant travel time, an adjustable backstop **28** is associated with each of the hammers **16**. It can also be noted from the above expression that variations in magnet flux densities can be initially compensated for by proper adjustment of the backstop **28**. The backstop **28** is adjustably mounted in a block **30** and since the resilient support members **18** and **20** normally urge the hammer against the backstop **28**, the position of the backstop establishes the rest position of the hammer.

In the use of the printing apparatus of FIGURE 1, a current is initiated in the coil **22** and as a consequence the interaction between the magnetic fields produced by the coil and the permanent magnets **24** and **26** generates a force propelling the coil to a position between the poles closest to the drum **10**. The hammer **16** urges the paper **14** and ribbon **12** against the drum **10** and is bounced back against the backstop **28**. As a consequence of continued engagement with the backstop **28**, the backstop is worn away or its shape becomes distorted. Consequently, the travel distance of each hammer changes thereby changing its travel time. As noted previously, variations in travel times cause misalignment of the printed characters. In accordance with the present invention, means are provided for reducing the wear on the backstop **28**. The reduction in wear is accomplished by reducing the amount of rebound energy retained by the hammer at the time it engages the backstop **28**.

Consider the hammer control circuitry of FIGURE 2. A code wheel **30** mounted to rotate synchronously with the drum **10** is provided. The code wheel **30** can, for example, be optically encoded to serve the purpose of identifying the characters moving into position in alignment with the hammers. Each character can be represented by a six bit binary code which can be read from the code wheel by six photosensitive elements **32** positioned on the side of the wheel remote from light source **33**. In addition to the code wheel **30** providing a six bit binary representation of each character prior to its moving into alignment with the hammers **16**, it also provides clock pulses which are read by photosensitive element **34** and which serve to define successive periods during which the characters move into alignment with the hammers **16**. In addition, the code wheel **30** carries information identifying whether each character is a low or normal area character and this information is read by photo-sensitive element **35**. The code wheel preferably comprises an optical device having a plurality of areas thereon each of which can be opaque to represent a binary "0" and transparent to represent a binary "1." Since the details of code wheels are well known in the art, they will not be considered here other than to point out that the code wheel need not be of the optical type but instead can be of the magnetic or mechanical type, for example.

The element **34** is connected to the input of a delay device **36** which provides in response to each clock pulse a pair of spaced pulses constituting an "actuate" and a "reset" pulse on lines **37** and **38**, respectively.

The elements **32** are connected to the input of a digital device such as a computer **38** in which is stored the information to be printed. The computer **40** compares each successive code read by elements **32** with the information to be printed and provides output signals which cause selected hammer coils **22** to be energized for each position of the drum. The computer **40** can either provide encoded address signals identifying particular hammers or

decoding means can be included within the computer so that the computer merely provides an output signal on each output line connected to a hammer to be actuated. In the latter case, which for the sake of simplicity will be assumed herein, a one to one correspondence exists between the number of hammers provided and the number of computer output lines.

The aforedescribed circuitry is common to the bank of hammer assemblies illustrated in FIGURE 1. Associated with each hammer assembly is a circuit **50** utilized to energize the coil **22** thereof at an appropriate time to cause information to be printed on the paper **14** in accordance with the character information stored in computer **40**. All of the circuits **50** are identical.

Each of the circuits **50** includes flip-flops **F1**, **F2**, and **F3**, all of which can be of the conventional set-reset type. One of the computer output lines is connected to the set input terminal of flip-flop **F1**. The true output terminal of flip-flop **F1** is connected to the input of And gate **52** along with output line **37** of delay device **36**. The output of gate **52** is connected to the set input terminal of flip-flop **F2**. The true output terminal of flip-flop **F2** is connected to the base of a transistor amplifier **T1** of the NPN type. The collector of transistor **T1** is connected through resistor **54** to a source of positive potential and the emitter of transistor **T1** is connected through resistor **56** to a source of negative potential.

The collector of transistor **T1** is connected to the base of a transistor **T2** of the PNP type which is connected in an emitter-follower arangement. More particularly, the emitter of transistor T2 is connected through resistor **58** to a first terminal of coil **22**, the second terminal of coil **22** being grounded. The collector of transistor T2 is connected to a source of negative potential. A first clamping diode **60** connects the first terminal of coil **22** to ground and a second clamping diode **62** connects the base of transistor T2 to the true output terminal of flip-flop F3. The output line **38** of delay device **36** is connected to the reset input terminals of flip-flops **F1**, **F2** and **F3**.

For purposes of illustrating the operation of circuit **50**, let it be assumed that resistor **56** is connected to a −50 volt potential, that the collector of transistor T2 is connected to a −35 volt potential and that the true output terminal of flip-flop F3 resides at −20 volts when it is set and at −30 volts when it is reset. In operation, just prior to the drum moving a new character into alignment with hammers **16**, the elements **32** will read the new character code from wheel **30**. The computer **40** will compare the new character code with the information to be printed and will provide true output signals on those of its output lines associated with the hammers **16** in the positions in which the new character is to be printed. As a result, flip-flop **F1** in certain ones of circuits **50** will be set. In addition, if element **35** indicates that the new character is a low area character, flip-flop F3 will be set.

Flip-flop F2 will be set in response to the generation of an actuate pulse on line **37** to in turn forward bias transistor **T1**. Consequently, the potential on the collector of transistor T1 and the base of transistor T2 will fall toward −50 volts but will be clamped by flip-flop F3 at either −20 or −30 volts. The application of the negative potential to the base of transistor T2 will forward bias transistor T2 and thereby cause a current to be driven through coil 22 whose amplitude is determined by the potential level established at the output of flip-flop F3 and whose duration is determined by the interval that flip-flop F2 remains set. This interval of course is equal to the delay between the actuate and reset pulses introduced by delay device **36**. Note well, that as a result of the emitter-follower arrangement, the current amplitude in coil 22 is relatively immune to variations in the potential level applied to the collector of transistor T2 so that, for example, this latter potential could vary from −35 to −40 volts without changing the current level through coil **22**. Diode **60** prevents the potential at the first terminal of coil 22 from going positive which might otherwise occur when transistor **T1** is off-biased.

Attention is now drawn to FIGURE 3 which illustrates the waveforms of voltages associated with the coil 22. The coil 22 can be energized to propel the hammer **16** against the drum by applying a neagtive voltage signal E_a to the coil and terminating it at time (*a*), prior to the time (*b*) at which the hammer propels the paper against the drum. This manner of energizing the coil is represented by the solid line in FIGURE 3. After the signal applied to the coil is terminated, the negative induced voltage signal E_i will be observed across the coil so long as the hammer is moving in a forward direction. After the hammer engages the drum at time (*b*), it will rebound from the drum and consequently a positive voltage will be induced in the coil.

The amplitude of the induced voltage E_i is equal to Blv where v is the velocity at which the coil conductor moves through the magnetic field established by the permanent magnets **24** and **26**. Consequently the induced voltage is directly proportional to the velocity of the hammer and the point in time (*b*) at which the induced voltage passes through zero approximates the point in time at which the hammer engages the drum. Similarly, point (*c*) approximates the time at which the hammer engages the backstop and rebounds forwardly thereby inducing a negative voltage in the coil. Point (*d*) represents another change of direction of the hammer and point (*e*) represents the point at which the hammer again rebounds from the backstop.

The wear on the backstop is of course proportional to the rebound velocity with which it is struck by the hammer. The hammer movement is characterized by very small frictional effects and the rebound velocity of the hammer can be equal to about one half the velocity imparted to it by the propelling force resulting from the interacting magnetic fields. It is possible to reduce backstop wear by reducing the velocity at which the hammer strikes the backstop. The hammer velocity can be reduced by applying the negative voltage E'_a represented by the dotted line in FIGURE 3 to the terminals of the coil in lieu of the negative voltage E_a represented by the solid line. That is, by applying a voltage tending to propel the hammer forwardly for a period which exceeds the forward travel time of the hammer, a portion of the energy imparted to the hammer by the collision with the drum will be dissipated. The duration of voltage E'_a is of course determined by the interval that flip-flop F2 remains set which in turn is controllable by the delay or spacing between the actuate and reset pulses generated by delay device **36**. Inasmuch as the applied voltage E'_a (dotted line) is applied for the full forward propulsion period of the hammer, its amplitude need not be as great as E_a (solid line) in order to obtain the same forward travel time of the hammer. By maintaining the voltage E'_a (dotted line) applied to the coil subsequent to time (*b*), the return velocity of the hammer will be reduced [as represented by the induced voltage E'_1 (dotted line)] inasmuch as the applied voltage E'_a (dotted line) will continue to tend to propel the hammer forwardly. This reduction in velocity, or braking, of the hammer will thereby reduce the wear on the backstop. Although, the reduced rebound velocity will cause the hammer to strike the backstop at a later time [i.e. at time (*f*) rather than time (*c*)] its total recovery time will be reduced as a result of a portion of its energy being dissipated.

From the foregoing, it has been shown how the wear on the backstop can be reduced by braking the hammer through the utilization of electrical braking means. More particularly it has been shown that by appropriately controlling the duration of the signal applied to the coil **22** carried by the hammer **16**, the same physical means utilized to propel the hammer against the drum can be

utilized to reduce the rebound velocity of the hammer from the drum.

In order to control printing intensity so as to prevent low area characters (e.g. ".") from appearing more intense than high area characters (e.g. "w") the energy with which the hammer strikes the drum can be reduced when a low area character is to be printed. Several different techniques can be utilized to reduce the striking energy. For example, when a low area character is to be printed, the forward movement of the hammers can be started sooner but with a lower velocity (lower applied voltage) so that the hammers strike the drum with less energy but at the same time they would have had the applied voltage not been lowered. A different and probably preferable technique is to start the forward movement of the hammers at the same time and reduce the amplitude of the signal applied to the coil so as to reduce the forward velocity of the hammer. By shifting the low area characters slightly backward on the drum to compensate for the extended hammer travel time, the characters will be printed in the appropriate position on the paper 14 with the desired intensity. That is, whereas the "." for example would naturally fall in the lower portion of a character position on the drum, it can be moved to an upper portion of a character position as shown in FIGURE 1. The element 35 detects a low area character by information coded on wheel 30. In response to a new character being a low area character, flip-flop F3 is set to cause its true output terminal to display a −20 volt potential, rather than −30 volts.

From the foregoing, it should be appreciated that means have been introduced herein for effecting both braking and printing intensity control over a printing hammer adapted to be used in a high speed printer. The means for effecting both of these functions makes use of the same means utilized to establish forward motion of the hammers, namely the interaction between the magnetic field produced by the coil carried by the hammer and the magnetic field produced by permanent magnets disposed proximate thereto.

The advantages gained as a result of the introduction of both of these control concepts are significant. Braking permits a reduction in backstop wear so that hammer travel times can be maintained constant for longer periods without requiring readjustment. As a result the quality of printing produced will be better for a longer period. Moreover, replacement of the backstops, hammers, and support means will be required less frequently inasmuch as they will be subjected to lower stresses thereby further reducing costs. In addition, braking reduces hammer recovery time thereby permitting an increased printing rate to be employed.

Printing intensity control of course provides a better quality printing product. In addition however, it also tends to reduce stresses and wear on both the hammers and drum by causing the hammers to strike the drum at a lower velocity whenever possible. Although, intensity control circuit means have been shown which distinguish between only two different degrees of density, it is to be understood that much more extensive control can be provided in accordance with the teachings of the invention to the end that the propelling force provided on the hammer can be made directly proportional to the area of a character to be printed.

What is claimed is:

1. In a high speed printing device including a movable printing surface and a plurality of printing hammer assemblies, each hammer assembly including a backstop; a hammer mounted for movement between said printing surface and said backstop; means normally urging said hammer into engagement with said backstop; means applying a first force to said hammer in a direction for propelling it against said printing surface for a duration which extends beyond the time said hammer strikes said printing surface to thereby reduce the rebound velocity of said hammer; said means for applying said first force to said hammer including a first energizable means carried by said hammer for producing a first magnetic field and a second means fixed relative to said hammer for producing a second magnetic field and means for selectively energizing said first means to thereby cause said first and second magnetic fields to interact.

2. The hammer assembly of claim 1 wherein said first means comprises a coil having first and second terminals.

3. The hammer assembly of claim 2 wherein said hammer is mounted on first and second spaced resilient support members constituting said means normally urging said hammer into engagement with said backstop; said first and second support members being electrically conductive and respectively connected to said first and second coil terminals.

4. A method of operating a printing hammer for causing it to strike a printing surface and for reducing the rebound energy thereof, said method comprising the steps of developing a resultant magnetic field for propelling said hammer against said printing surface; and maintaining said magnetic field subsequent to the time said hammer strikes said printing surface to this reduce the rebound velocity of said hammer.

5. In a high speed printing device including a printing surface having a plurality of low and high area printing characters thereon and a hammer assembly including a hammer adapted to strike said printing surface, means for moving said printing surface past said hammer for causing each of said printing characters to successively move into alignment with said hammer; first character identifying means for defining the succeeding one of said plurality of printing characters which is to move into alignment with said hammer; second character identifying means for defining one of said plurality of printing characters to be struck by said hammer; comparison means for providing an indication when the characters defined by said first and second character identifying means are identical; and means responsive to said indication provided by said comparison means for applying a first force to said hammer for propelling it against said drum surface if said defined character is a low area character and for applying a second force to said hammer for propelling it against said drum surface if said defined character is a high area character.

6. The printing device of claim 5 wherein said means for applying said first and second forces to said hammer includes a first means carried by said hammer for producing a first magnetic field and a second means fixed relative to said hammer for producing a second magnetic field and means for applying a signal having a first amplitude to said first means in response to the provision of said indication if a low area character is defined and for applying a signal having a second amplitude to said first means if a high area character is defined.

7. The printing device of claim 6 wherein said first means comprises a coil having first and second terminals.

8. The printing device of claim 7 wherein said hammer is mounted on first and second spaced conductive support members; said first and second support members being electrically conductive and respectively connected to said first and second coil terminals.

9. In a high speed printing device including a printing surface having a plurality of low and high area printing characters thereon and a hammer assembly including a hammer adapted to strike said printing surface, means for moving said printing surface past said hammer for causing each of said printing characters to successively move into alignment with said hammer; first character identifying means for defining the succeeding one of said plurality of printing characters which is to move into alignment with said hammer; second character identifying means for defining one of said plurality of printing characters to be struck by said hammer; comparison means for providing an indication when the characters defined by said first and second character identifying means are identical; means

responsive to said indication provided by said comparison means for applying a first force to said hammer for propelling it against said drum surface if said defined character is a low area character and for applying a second force to said hammer for propelling it against said drum surface if said defined character is a high area character; and means for terminating said first or second force applied to said hammer subsequent to said hammer striking said printing surface.

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WILLIAM B. PENN, *Primary Examiner.*