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(54) **Impact printers.**

(57) An impact printer (10) includes a platen (18), a carriage (32) mounted for reciprocating movement generally parallel to the platen, a rotatable print element (50) having character imprinting portions disposed thereon, the characters being assigned a class designation according to their imprinting area, a print element selector for moving the print element to position a selected character portion at a printing position, a hammer (82) for driving the character portions to deform the platen, and means for driving the hammer toward and away from the platen. Different impact speeds are assigned to the hammer in accordance with the character portion class designations. The rate of hammer displacement is varied as it is moved from a home position to an impact position so that the hammer initially moves through a first region at an increasing speed and subsequently moves through a second region at a substantially-constant speed. A counter is incremented periodically in response to the hammer movement for determining the instantaneous location and speed of the hammer, and the counter is reset with a predetermined count, notwithstanding the actual count, at a location within the second region.

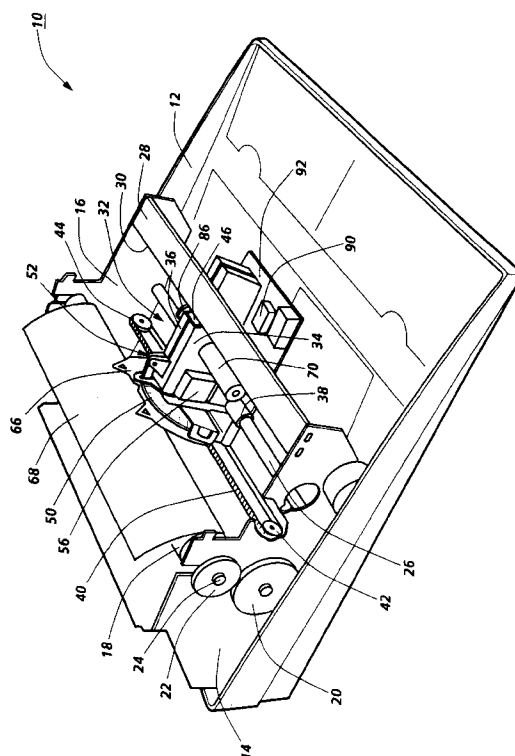


Fig. 1

This invention relates to a controlled low frequency impact system for a quiet impact printer, wherein variable impact speeds are utilized to impart different amounts of kinetic energy to character elements of different size, and to an inexpensive system for precise bidirectional motor control without the need for direction information from the feedback sensor.

5 The office has, for many years, been a stressful environment because of the large number of objectionable noise generators, such as typewriters, high-speed impact printers, paper shredders, and other office machinery. Where several such devices are placed together in a single room, the cumulative noise pollution may even be hazardous to the health and well being of its occupants. The situation is well recognized and has been addressed by governmental bodies which have set standards for maximum acceptable noise levels in office environments. Attempts have been made by office machinery designers, in the field of impact printers, to reduce the noise pollution. Some of these methods include enclosing impact printers in sound-attenuating covers; designing impact printers in which the impact noise is reduced, and designing quieter printers based on non-impact technologies, such as ink jet and thermal transfer.

15 The low-cost personal typewriter is purchased primarily for home usage (including both personal and in-home office) and for school usage. It is particularly desirable in these environments to reduce the acoustic noise level of the printing mechanism, at the source, to levels which are unobtrusive. For example, in the home, other members of the family should not be distracted by the clatter of typing if conducted in common rooms. In a secondary school or college setting, colleagues and others should not be disturbed if the user types in a library, a study hall or a dormitory room. Heretofore such usage has not been possible because typewriters are notoriously noisy devices. The quiet operation of the low-cost typewriter of this invention will enable such usage, because quietness transports such useful appliances into new physical settings and enhances portability. A derived benefit will be freer communication among work group members, as the user is able to work directly in the group in a non-irritating manner.

25 Design changes in low-cost typewriters have been introduced in order to reduce their output noise levels. Maintaining a competitively marketable product becomes a challenge in the consumer, or commodity, market segment, where product cost is in the \$ 100 to \$300 range. For example, a \$100 typewriter would typically have a unit manufacturing cost of about \$65. Clearly, any modification necessitated by the implementation of a sound-reduction design will of necessity be extremely low in cost because the incremental increase in product cost to the consumer will not warrant a large percentage rise in this market segment.

30 Noise measurements are often referenced as dB or dBA values, wherein the "A" scale represents humanly-perceived levels of loudness, as opposed to absolute values of sound intensity. When considering sound energy represented in dB (or dBA) units, it should be noted that the scale is logarithmic, and that a 10 dB difference equals a factor of 10, a 20 dB difference equals a factor of 100, a 30 dB equals a factor of 1000, and so on.

35 Typical typewriters generate impact noise in the range of 65 dBA to just over 80 dBA, when measured at the operator's position. These sound levels are deemed to be intrusive. For example, the IBM Selectric ball unit generates about 78 dBA, while the Xerox Memorywriter generates about 68 dBA, and the low-cost Smith Corona Correcting Portable generates about 70 dBA. When reduced to a dBA in the high 50s, the noise is identified as being objectionable or annoying. It would be highly desirable to reduce the impact noise to a value in the vicinity of 50 dBA. The low-cost typewriter of the present invention has been typically measured at about 40 50 dBA, representing a dramatic improvement, on the order of about 100 times less sound pressure, over presently-available low-cost typewriters.

45 The major source of noise in the modern typewriter is produced as the hammer impacts and drives a character pad to form an impression on a receptor sheet. Character pads are carried upon and transported past a print station at the ends of the rotating spokes of a printwheel. When a selected character is to be printed, it is stopped at the print station and a hammer drives it against a ribbon, the receptor sheet and a supporting platen, with sufficient force to release ink from the ribbon onto the receptor sheet.

In conventional ballistic hammer impact typewriters, a hammer mass of about 2.5 grams is ballistically propelled by a solenoid-actuated clapper toward the character/ribbon/paper/platen combination. After the hammer hits the rear surface of the character pad, its momentum continues to drive it toward and against the ribbon/paper/platen combination and to deform the platen surface. Once the platen has absorbed the hammer impact energy, it seeks to restore its normal shape by driving the hammer back to its home position where it must be stopped, usually by another impact. This series of high-speed impacts is the main source of the objectionable impact noise in these printers.

55 Typically the duration of platen deformation by the very small impacting hammer mass is very short, of the order of 100 microseconds. Intuitively it is known that a rapid impact will be noisy and that a slow impact will be quieter. Thus, if the impact duration were longer it would be possible to make the device quieter. In typewriters with printing speeds in the 10 to 12 characters per second range, the mean time available between charac-

ter impacts is about 85 to 90 milliseconds. Clearly, more of that available time can be used for the hammer impact than the usual 100 microseconds. If, for example, the platen deformation time were stretched to even 5 to 10 milliseconds, this would represent a fifty-to one hundred-fold increase in the impact pulse width. It is also intuitive that, in order for a slow impact to deform the platen by the same amount as does the rapid impact, for adequately releasing the ink from the ribbon, a larger hammer mass (or effective mass) must be used. This is because manipulation of the period of the deformation changes the frequency of the sound waves resulting therefrom. As the deformation period is stretched, the sound frequency (actually a spectrum of sound frequencies) resulting from the deformation is proportionately reduced, and the perceived noise output of the lower frequencies is reduced. Since this is a resonant system, the mass will be inversely proportional to the square of the frequency shift. Therefore, a one hundredfold increase in the time domain (100 microseconds to 10 milliseconds) will proportionately reduce the frequency output when a ten thousandfold increase in the mass is effected. Clearly it would not be practical to increase the actual mass of the hammer by such a factor. As an alternative to increasing the hammer *mass per se*, its effective mass may be increased by means of a mechanical transformer.

The general concept implemented in the present typewriter, i.e. reduction of impulse noise achieved by stretching the deformation pulse and impacting with an increased hammer mass, has been recognized for many decades. As long ago as 1918, in US-A-1,261,751 quieter operation of the printing function in a typewriter was proposed by increasing the "time actually used in making the impression". A type bar typewriter operating upon the principles described in this specification was commercially available at that time.

The impact printer incorporating the theory of operation of the present invention is explained in US-A-4,681,469 which discloses greatly increasing the effective mass of the hammer, introducing the hammer to the platen at a relatively-slow speed, and causing the platen deformation to take place over an extended period. US-A-4,668,112 discloses controlling the movement of the hammer throughout its path of movement from its home position to its application of impact force to the platen. As the hammer nears the surface of the platen its speed is significantly diminished by a braking action of the drive motor, so that impact takes place at a very slow speed. Subsequent to initiation of contact, the drive motor is reenergized, increasing the hammer force to deform the platen.

In both the '469 and '112 patents a mass transformer, comprising a heavy rockable bail bar driven by a voice coil motor, urges a push rod toward and away from the platen in a controlled manner. The push rod in turn moves a print tip (hammer) into deforming contact with the platen. A sensor mounted upon the print tip indicates the moment of contact with the platen, so that an additional application of kinetic energy may be provided by the voice coil motor at that juncture. A suitable controller energizes the voice coil motor to move the print tip across a throat distance between its home position and the surface of the platen, where its speed is very slow. After contact has been sensed, the controller again energizes the voice coil motor for imparting a predetermined force for deforming the platen to release ink from the ribbon with this high effective mass.

A low cost implementation of a quiet impact printer, based upon the principles of operation of the '469 and '112 patents, is described in copending patent application U.S. Serial No. 07/510,654 (Babler et al) assigned to the same assignee as the instant application, whose disclosure is herein fully incorporated by reference. A high effective mass hammer is driven toward and away from the platen, by a DC motor acting through a displacement and force modifying mechanism, in a timed manner. When the hammer impacts the platen, contact is sensed as a sudden change in speed and then a pressure force is applied by the motor. In the low cost quiet impact printer designed substantially in accordance with the teachings of the copending Babler et al application, wherein a DC motor and cam control the print hammer motion, significant power is used to accelerate and decelerate the motor armature for prepositioning the hammer immediately prior to contacting the platen. The power requirements are further increased because of the elasticity of the mechanical system which necessitates an extended duration of the post-contact pressure ("squeeze") force for adequate ink release from the ribbon. Furthermore, the precision DC motor control systems, as incorporated therein, typically use expensive servo controls with various types of feedback elements. In particular, such systems requiring bidirectional start/stop motion almost always include some means for deriving directional information about the motor. Without directional signals, along with position pulses, the controller could encounter instances where counting errors occur due to mistakes about direction. In sum, while the acoustic characteristics are quite attractive, the speed of operation is limited, the power demand on the control electronics is significant, and the control system is expensive.

It is the primary object of the present invention to decrease the power requirements of a low-cost quiet impact printer by foregoing the fixed approach speed and variable "squeeze" force method of operation in favor of varying the contact speed of the hammer tip for characters of different size. Increases in audible emissions should be barely perceptible, because the natural frequency of the impact sounds is still very low. The present invention may be carried out, in one form, by providing an impact printer comprising a platen, a carriage moun-

ted for reciprocating movement generally parallel to the platen, a rotatable print element having character-imprinting portions disposed thereon, the characters being assigned a class designation according to their imprinting area, a print element selector for moving the print element to position a selected character portion at a printing position, a hammer for driving the character portions to deform the platen, and means for driving the hammer toward and away from the platen. The carriage supports the print element, the selector, the hammer and the driving means. The invention comprises means for assigning different impact speeds to the hammer in accordance with the character portion class designations, means for varying the rate of hammer displacement as it is moved from a home position to an impact position, so that the hammer initially moves through a first region at an increasing speed and subsequently moves through a second region at a substantially-constant speed, and means for controlling the attainment of the impact speeds, including means for incrementing a counter periodically in response to the hammer movement for determining the instantaneous location and speed of the hammer, and means for resetting the counter with a predetermined count, notwithstanding the actual count, at a location within the second region.

The present invention will now be described by way of example with reference to the accompanying drawings, wherein:

Figure 1 is a perspective view of an impact printer of the present invention;

Figure 2 is a schematic partial plan view of the printer shown in Fig. 1;

Figure 3 is a schematic side elevation of the printer;

Figure 4 is a enlarged side elevation showing the relationship between the hammer, its driving cam, the timing disc and a sensor;

Figure 5 is a graphical representation of the hammer cam transfer characteristics;

Figure 6 is a phase diagram showing typical print cycles, for characters of different size; and

Figure 7 is a state diagram of the print cycle of the printer of the present invention.

The impact printer 10 housed within a cover set (only the base 12 is shown) includes relatively few moving parts. Vertically-upstanding left-and right-side support plates 14 and 16 are each secured to the base 12 and support the ends of platen 18 in seats therein. The platen is driven by a suitable motor (not shown) through a gear train including driving gear 20 and driven gear 22 on the platen shaft 24. The side plates also support the ends of a highly-polished guide rod 26 and the ends of reaction bar 28 having an accurately-machined guiding edge 30 facing the platen. The reaction bar is mounted so as to be capable of adjustment in order to maintain the guiding edge 30 parallel to the platen surface and to establish accurately its distance from the platen.

A printer carriage 32, comprised of carriage frame plates 34 and 36, each having a bearing 38 mounted thereon, is supported upon the guide rod 26 for reciprocating movement therealong, across the length of the platen. Carriage reciprocation is controlled by a motor (not shown) which drives a toothed spacing belt 40 (a cable or rack drive may be used instead) secured to the carriage, over pulleys 42 and 44. As the carriage 32 moves along the guide rod 26 on bearings 38, it will tend to rotate in a clockwise direction thereabout (as viewed in Figure 1), under the influence of gravity, and biases bearing shoe 46 against the guiding edge of reaction bar 28. The shoe is made of a hard, low-friction material. This carriage mounting arrangement facilitates inexpensive assembly of the printing device because it eliminates criticality in the placement of the guide rod, requiring only one element, the reaction bar 28, to be accurately positioned. By adjusting the ends of the reaction bar relative to the side plates 14 and 16, the guiding edge 30 may be accurately positioned parallel to the platen, so that as the carriage 32 traverses the printer, all the printing elements carried thereon will remain in their proper position relative to the platen.

The printing elements comprise a printwheel 50, a hammer assembly 52 and a ribbon pack assembly 54 (seen in Figure 3). A printwheel drive motor 56 mounted on the carriage frame plates 34 and 36 has a drive coupling 58 to which a printwheel hub 60 may be connected for rotation of the character pads 62 (located at the ends of printwheel spokes 64) past a print station adjacent to the platen. Selective rotation of the drive motor 56 under processor control, initiated by keystrokes, locates and arrests the desired character pad 62 at the print station. A resilient card guide 66 also mounted on the carriage frame plates holds an image receptor sheet 68 in intimate contact with the platen surface.

The hammer assembly 52 is best seen in Figures 3 and 4, wherein carriage frame plate 36 has been cut away to reveal it better. A hammer-actuating DC motor 70 is mounted upon carriage frame plate 34, with its drive shaft 72 extending through and beyond both frame plates. Hammer drive cam 74 secured to the shaft 72 moves cam follower 76 to rotate bell crank 78 about pivot pin 80. The hammer 82 is pinned at the opposite end of the bell crank and slides through a stationary guide bearing 84. As the motor rotates it also drives timing disc 86 relative to a fixed sensor 88 for generating a location count in motor controller 90, mounted upon circuit board 92. Although the circuit board is illustrated as being secured to the carriage, it is possible to mount it on the base. The motor controller sends signals to the DC motor for effecting cam rotation at a desired speed and in a desired direction.

As taught in the '469 and '112 patents, in order to achieve low impact noise, the hammer must initiate contact at a very low speed (under 400 mm per second), but in order to achieve a satisfactory printing speed, it must move rapidly across the throat. These movement characteristics are determined by the profile of hammer drive cam 74 and the DC motor rotational speed as determined by the controller 90. A representation of the cam displacement characteristics can be seen in Figure 5. A first cam region 74a will result in the illustrated rapid hammer displacement, in which harmonic motion has been selected to move the hammer smoothly for minimizing acoustic noise associated with cam transition points and for reducing cam and cam follower wear. A second, linear, cam region 74b will result in the shallow straight line displacement (e.g. 0.025 mm/degree of motor rotation) over the region from x_1 to x_2 (corresponding to angles a_1 and a_2 of the cam) in which impact is expected. i.e. from the surface of a multi-sheet pile (x_1) to the surface of a single sheet (x_2). The linearity of this second cam region results in a linear relationship between the motor current and the hammer force, so that its slope may be selected to yield the maximum force needed for a particular system in view of the torque available from the motor.

The print force is resolved as the hammer 82 is driven against the platen and the shoe 46 is driven against the reaction bar 28. Ideally, if the hammer and the reaction bar were aligned, the print force and the reaction force would be equal and opposite and no other system elements would experience any force at impact. However, in view of design constraints, it is often not possible to align these forces, in which case there will be a force through the carriage and other elements of the system, including the guide rod 26, all of which should be as low as possible.

Rather than using a fixed approach speed which is slowed substantially prior to impact, followed by a variable "squeeze" force, it has been that the efficiency of the quiet impact printing method can be improved by impacting the platen with the hammer approaching at various approach speeds, in accordance with the size of the character to be printed. The former method is less efficient, because it requires the motor to accelerate the large hammer mass and then to decelerate it solely to traverse the throat distance, but it is slightly quieter in operation. It is well known in conventional impact printers to impact characters of different size with different hammer forces, but this has always been accomplished with a high impact speed and a relatively small mass, i.e. in very noisy systems. By ensuring that the contact speed is relatively low (i.e. less than 400 mm/s, the present invention will result in a controlled low-frequency impact. Also, the effective hammer mass at the moment of impact must be greater than 0.25 kg, and the platen deformation period greater than 1 millisecond.

The following Table indicates four classes of characters, based upon their impact area, and the hammer tip speed required by each for obtaining the printing force needed for good ink release and maintaining quiet operation. It should be understood that a finer-grained control is possible by grouping the characters into more classes.

Character	Force (lbs)	Tip Speed (ips)	Curve (Fig. 6)
W	22	8	A
x	12	4.5	B
i	9	3	B/C
.	4	1.5	B/D

TABLE 1

Because the present invention eliminates the need for hard forward and reverse driving of the DC motor, for moving the hammer tip across the throat distance, it requires significantly lower power. As illustrated in Figure 6 and set forth in the above Table, the motor drives the hammer tip to achieve a desired speed (and maintain it) just prior to impact with the platen. Curve A represents the speed response for characters needing the highest energy level, and curve B represents the speed response for the most-frequently used impact levels (i.e. the "x" and similar characters). The target speed for these high energy curves is achieved and maintained prior to the initiation of the impact zone (i.e. the location at which impact may be expected). For the low energy curves C and D, the system is slowed down from curve B to the desired lower target speed at one or more predeter-

mined points. The alternative of accelerating the system from the starting point directly to the C and D target speeds is not efficient for these low energy levels since it would significantly extend the print cycle time.

In any system requiring bidirectional start/stop motion, it is imperative to maintain precise information regarding speed and location of the motor/cam/hammer. Such systems almost always include some means for deriving direction information in order to increment and decrement the counter for maintaining accurate position information. Knowledge of direction is a safeguard, because there are instances during rotation and counter-rotation of these elements when some accidental event causes the direction to change by mistake, resulting in counting errors. Usually an optical encoder assembly is incorporated from which position, speed and direction may be determined. Such an interruptive encoder assembly may comprise a radially-slotted timing disc, mounted upon the motor drive shaft, and a sophisticated IC sensor mounted in a housing positioned relative to the disc. The sensor typically employs a single light source (e.g. a light-emitting diode), two accurately positioned photodetectors, and logic circuitry which provides two outputs: a counting pulse generated whenever the illumination level on one of the photodiodes passes through a threshold level, and a direction output which is set in response to which of the two channels is illuminated first. Such a device is referred to as a dual channel sensor.

A simple sensor is typically used in systems where the controller is using the output information for counting, determining speed, and/or detecting a stop position. Such a sensor (referred to as a single channel sensor) employing a single light source and a single detector will not yield direction information. These systems often use an interrupting timing disc with a unique location feature such as a flag, or wide slot (for use in a transmissive mode), or a wide reflective element (for use in a reflective mode), whose width dimension is a multiple (such as 3x) of the width of the remaining circumferential interrupting features (narrow slots or reflective stripes). The flag may be easily detected and differentiated by a controller. In conventional systems, the location feature is usually phased with a desired stopping position of the mechanism. Thus, its controller simply uses the period (T_s) of the slot count pulses for speed control, and the absence of pulses for a predetermined time (T_F), as the sensor passes the flag, for detecting the stopping position. It should be clear that these systems must operate at a uniform speed, particularly when nearing the flag location, so that the comparison of T_F with T_s will be accurate, since deceleration in advance of the stop position (increasing the slot time intervals T_s) makes detection of the flag very difficult.

The accurate timing of motor control events is achieved by this invention with only a simple sensor which generates a signal indicative of the presence or absence of light. In Figure 4 there is illustrated the timing disc 86 having radial interrupting features (narrow slots) 94 and flag (wide slot, comparable to three narrow slots) 96 movable past the fixed simple sensor 88. The flag is placed relative to the cam at a location intermediate the motion end points, where the rotational speed is expected to be substantially constant and the direction of movement is known.

When the flag is sensed ($T_F \gg T_s$) a position counter in the controller 90 is reset to a predetermined count, thereby calibrating the system each time the flag is sensed. By resetting the counter at this point in the cycle, the location is always known at a critical point from which the controller will count to the location at which it will instruct the motor to initiate braking so as to impact the platen at the predetermined speed for the character to be printed. It will make no difference in the operation of this printer if there have been errors in the count prior to the reset, since the slate will be wiped clean and the new information will prevail. This sensing system, which is inherently unsophisticated, enables relatively-sophisticated control functions to be performed. In addition, by substituting a simple sensor for a sophisticated sensor, the cost saving is substantial relative to the approximately \$65 cost of manufacturing a \$100 typewriter.

Turning to Figure 7 there is illustrated a state diagram showing the programmed print cycle as used in the present invention with a simple sensor, and employing variable impact speed for achieving low-cost quiet impact printing. The program performs the following series of routines, wherein exemplary values for times and location are set forth:

In START UP PREPARATION, a look-up table in the controller 90 is used to determine the desired impact energy (speed) for the character to be printed. As shown in Table 1 and Figure 5, four impact speed classes have been selected. It is certainly possible to assign more, if needed. From the curve of Figure 5, it can be seen that, starting from a home position, an initial target speed is selected. For high-energy characters (curves A and B) the impact speed will be the initial target speed. For low-energy characters (curves C and D) the lower impact speed would be too low to be used for traversing the throat, so the initial target speed will be the higher speed of curve B.

In BEGIN MOVING, a high forward drive along either curve A or B is initiated. In order to validate the timing increments used for detecting the flag, an initialization loop is implemented. This is done by setting an initial target location equal to the present location plus three counts, and then driving forward until the initial target location is reached. Then the program starts looking for the flag. As the timing disc rotates, a counter is incremented at each interrupt ion of the sensor.

In LOOK FOR FLAG, the program enables a detect-flag routine which monitors the time between slots, and establishes in memory a flag-present time when a slot time value is greater than twice the time value between the prior two slots (i.e. $T_F \gg T_S$). After enabling this routine, the program continues to monitor the speed of the motor as determined by the time it takes between slots (T_S). A drive/coast loop subroutine allows the initial target speed to be achieved. If the present speed is slower than the initial target speed (set at the start), the motor is instructed to drive, and if the present speed is faster than the initial target speed the motor is allowed to coast.

In FLAG FOUND, when the 2x time is detected, the location counter is RESET to a predetermined value depending upon the direction of rotation of the motor, and taking into consideration the missed counts attributable to the wide slot. Currently count 161 is used when advancing to the platen, and count 166 when retreating from the platen. The existence of the flag will disrupt the speed determination because, when the 2x slot time is detected, it could be interpreted as a slowing of the motor and the controller would attempt to drive the motor hard to bring it back up to speed. Instead, the program continues to drive the motor at the same state as immediately prior to the flag being detected until several post-flag sensor interrupts occur and the speed data can again be used.

In APPROACHING IMPACT ZONE, the character to be printed is tested to determine if it is a low-energy or a high-energy character. (a) If the character is a high-energy character (curves A or B), the speed is tested to determine if it is faster or slower than its target value. If it is faster, low current reverse drive and dynamic braking are used until the correct impact speed is achieved. If the speed is equal to or slower than the target speed the drive/coast loop is effected until the impact zone. (b) If the character is a low-energy character (curves C or D) the detected speed will be greater than the target impact speed and a low-current reverse drive is initially applied to decelerate the hammer rapidly to a predetermined lower speed, followed by dynamic braking until the correct target impact speed is reached. This speed is then maintained by a drive/coast loop until the hammer is at the impact zone.

In AT IMPACT ZONE, the hammer will be in the drive/coast loop at the target speed. The value of the low drive current is chosen such that it is adequate to maintain the speed, unless the hammer motion is reduced by IMPACT, which is assumed to have occurred when the hammer speed drops to half the target speed. At this point the hammer is put into a coast state and allowed to remain in that state for 5 milliseconds to allow it to continue its forward progress and begin to rebound. Then the hammer is retracted toward its home position.

In START RETRACT, the program begins retracting the hammer with a low reverse drive for 3 milliseconds in order to get the hammer moving. Typically this routine is needed only with low-energy characters because the high-energy characters have a high enough rebound speed.

In LOOK FOR FLAG, the reverse drive is increased to a predetermined value and the return target speed is maintained by the drive/coast loop until the flag is again encountered. When the 2x slot time (i.e. $T_F \gg T_S$) is detected (FLAG FOUND), the location counter is again RESET (to count 166 in this direction) and the return target speed is maintained by the drive/coast loop until a predetermined location is reached in the vicinity of the home location (at count 130).

In ENDING CYCLE, at a predetermined location a two-step deceleration routine is used to bring the hammer to rest. First, a low current forward drive rapidly slows it until the time between slots is greater than 2 milliseconds, then dynamic braking completely stops the motion, as indicated by the time between slots being greater than 5 milliseconds.

In the high-energy cases (A and B), the target speed is maintained substantially all the way from the reset point to the platen surface. However, in the low-energy cases (C and D) a transition point, at which deceleration is initiated, is selected some number of counts after the RESET point. It is important to reduce the time spent at the low target speed because the low speed affects print speed adversely. Optimally, it is desired to achieve the correct target speed just in time. Therefore, the program constantly updates in memory the count at which impact is sensed and how long it took to decelerate to the predetermined impact speed. In this way, the transition point may be adjusted based upon performance of the preceding cycle.

Claims

1. An impact printer (10) comprising a platen (18), a carriage (32) mounted for reciprocating movement generally parallel to the axis of the platen, a rotatable print element (50) having character-imprinting portions disposed thereon, the characters being assigned a class designation according to their imprinting area, a print element selector for moving the print element to position a selected character portion at a printing position, a hammer (82) for driving the character portions to deform the platen, and means for driving the hammer toward and away from the platen, the carriage supporting the print element, the selector, the ham-

mer and the driving means,

means for assigning different impact speeds to the hammer in accordance with the character portion class designations,

5 means (90) for varying the hammer speed as it is moved from a home position to an impact position so that the hammer initially moves through a first region wherein it moves at an increasing speed and subsequently moves through a second region wherein it moves at a substantially-constant speed, and

10 means for controlling the attainment of the impact speeds, including means for incrementing a counter periodically in response to the hammer movement for determining the instantaneous location and speed of the hammer, and means for resetting the counter with a predetermined count, notwithstanding the actual count, at a location within the second region.

2. The printer as claimed in claim 1, wherein the hammer having an effective mass of at least 0.25 kg and an impact speed no greater than 400 mm per second at the location where the character portion initially deforms the platen, and in which the character portion deforms the platen for a contact period of at least 15 1 millisecond.

3. The printer as claimed in claim 1 or 2, wherein the control means comprises a signal emitter and collector (88) and a signal interrupter (86).

20 4. The printer as claimed in claim 3, wherein the signal emitter and collector comprise a single-channel sensor.

5. The printer as claimed in any preceding claim, wherein the driving means comprises a motor (70) having a drive shaft (72), the means for varying the hammer speed comprises a cam (74) mounted upon the drive shaft and having a first portion for moving the hammer through the first region, and a second portion for moving the hammer through the second region, and wherein the signal interrupter comprises a timing disc (86) mounted upon the drive shaft.

30 6. The printer as claimed in claim 5, wherein the timing disc has an annular row of narrow slots located near its periphery, there being a single slot in the row which is substantially wider than the narrow slots, the wide slot and the sensor being located relative to the cam such that the wide slot is sensed after the hammer enters the second region in its travel toward the platen.

35 7. The printer as claimed in any preceding claim, wherein the means for resetting the counter is actuated as the hammer approaches the platen, and as the hammer leaves the platen.

40 8. A method of impact printing, comprising the steps of moving a rotatable print element (50) having character imprinting portions disposed thereon past a printing zone adjacent a platen (18), arresting a selected character imprinting portion at the printing zone, moving a hammer (82) toward and away from the platen for driving the selected character imprinting portion to deform the platen with a printing force, assigning a class designation to each character imprinting portion according to its imprinting area, assigning different impact speeds to the hammer in accordance with the class designations, varying the hammer speed as it is moved from a home position to an impact position by initially rapidly displacing the hammer through a first region at an increasing speed, and subsequently displacing the hammer through a second region at a substantially-constant speed, and 45 controlling the attainment of the impact speeds by incrementing a counter periodically as the hammer is moved and determining the instantaneous location and speed of the hammer from the count, and resetting the counter with a predetermined count, notwithstanding the actual count, at a location within the second region.

50 9. The method as claimed in claim 8, wherein the step of varying the hammer speed further includes the step of achieving the impact speed and maintaining it until the hammer impacts the platen.

55 10. The method as claimed in claim 8, wherein the step of varying the hammer speed further includes the steps of reducing the speed of the hammer to the impact speed, subsequent to the resetting, step of and maintaining the impact speed until the hammer impacts the platen.

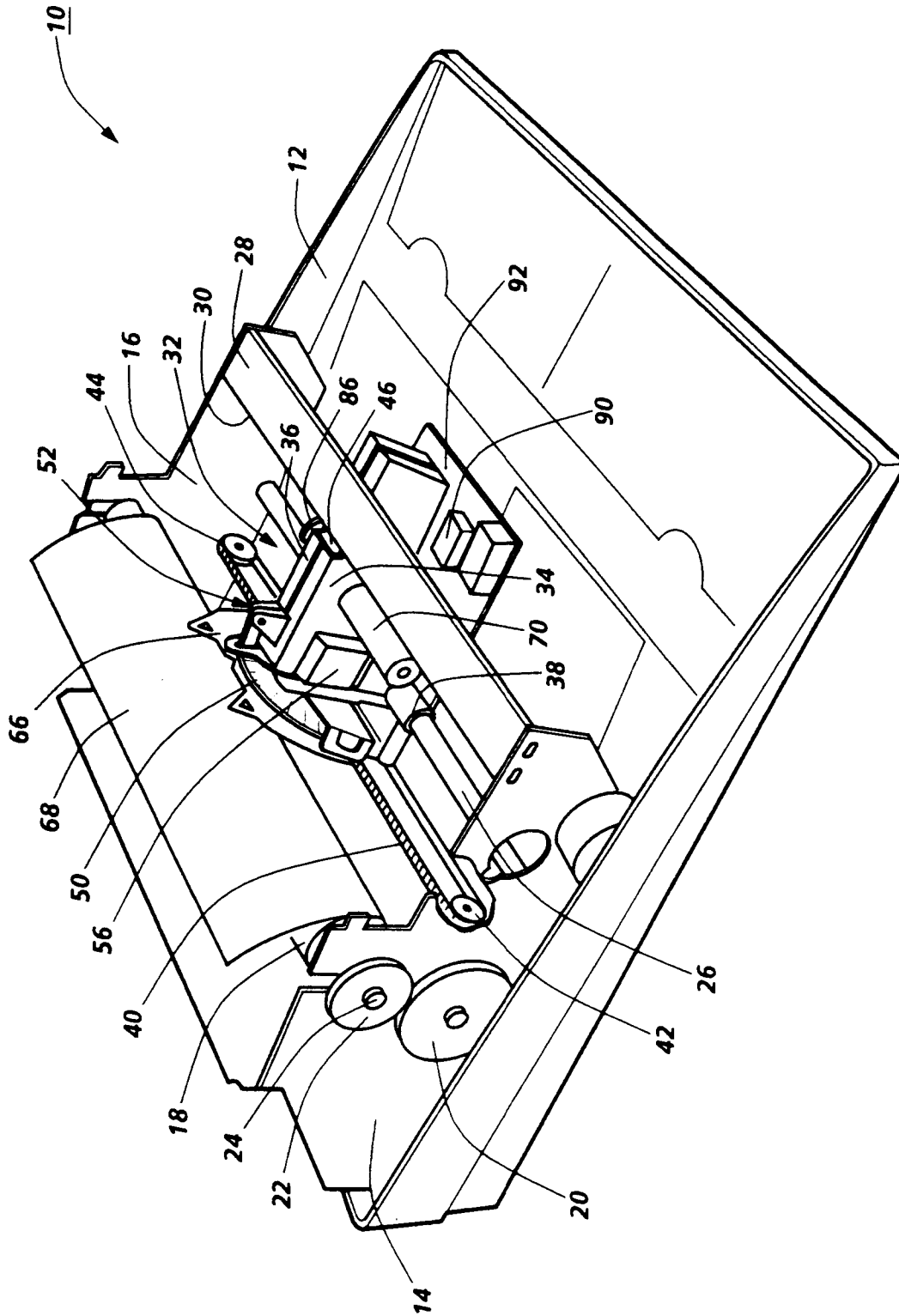


Fig. 1

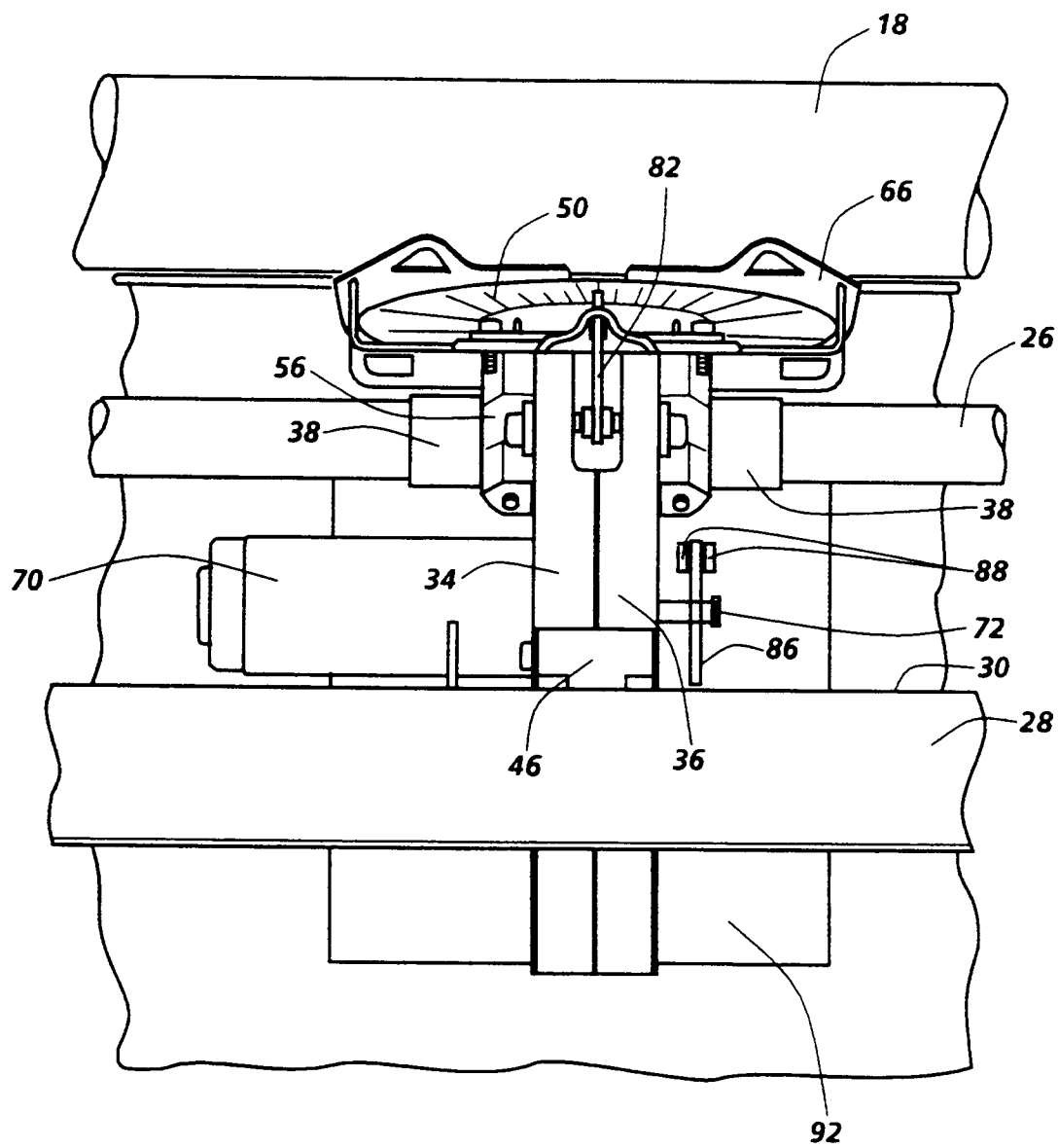


FIG. 2

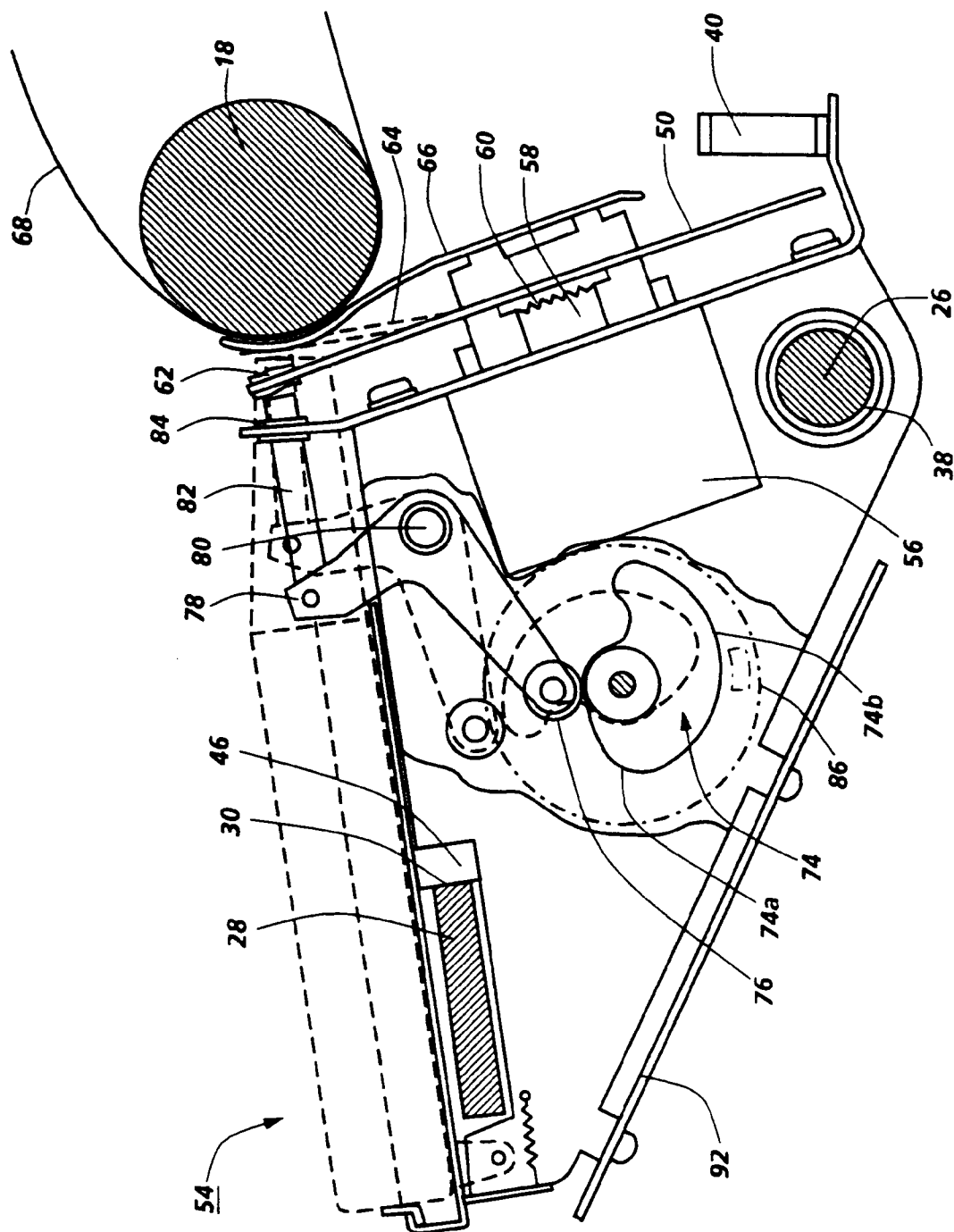


Fig. 3

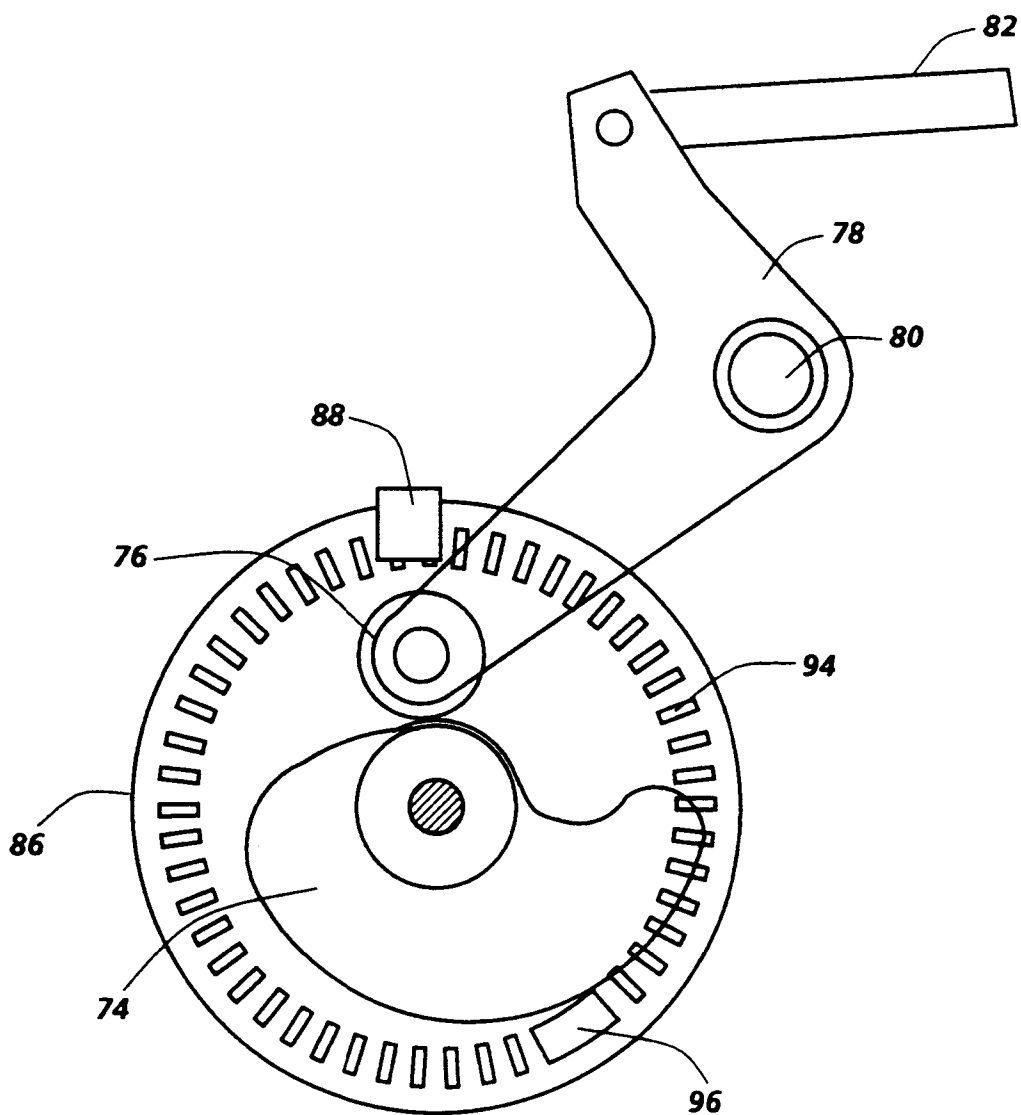


Fig. 4

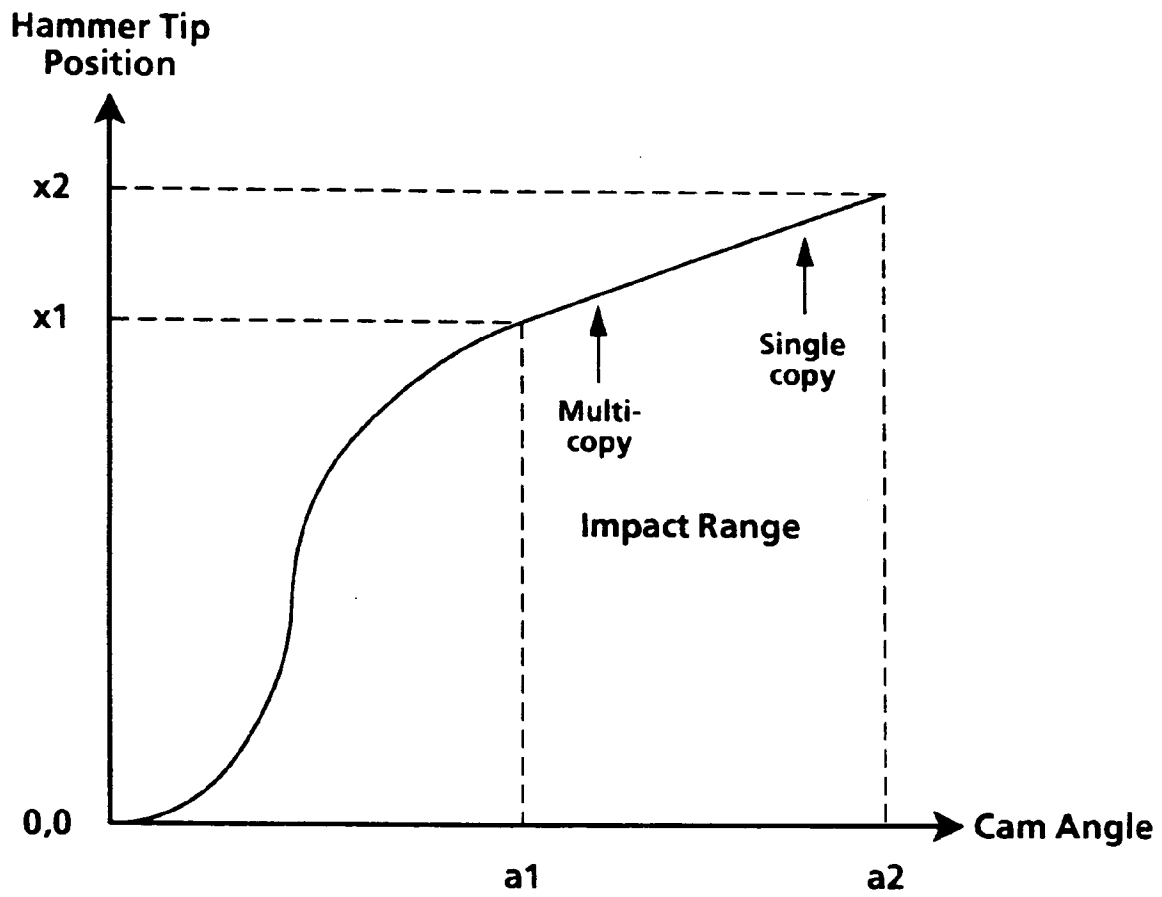


Fig. 5

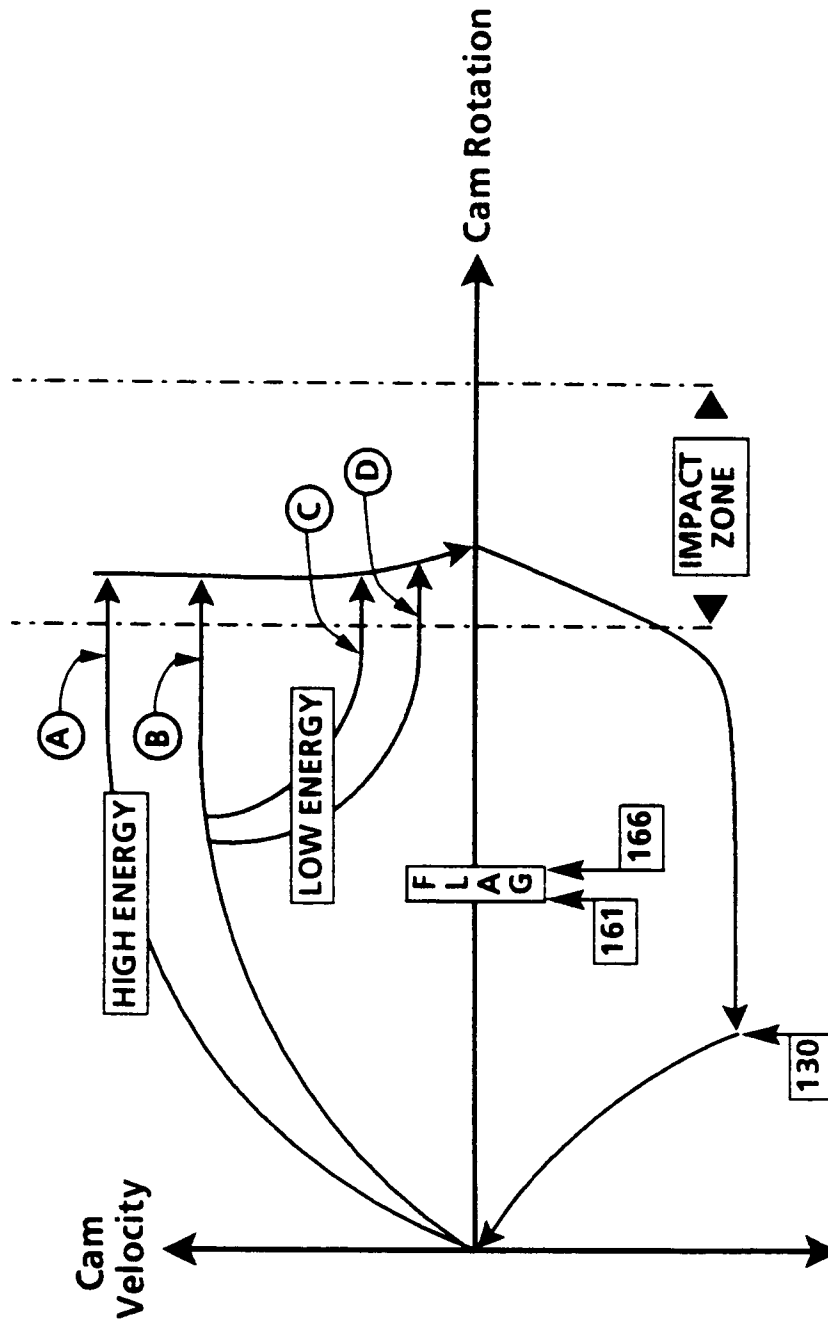


FIG. 6

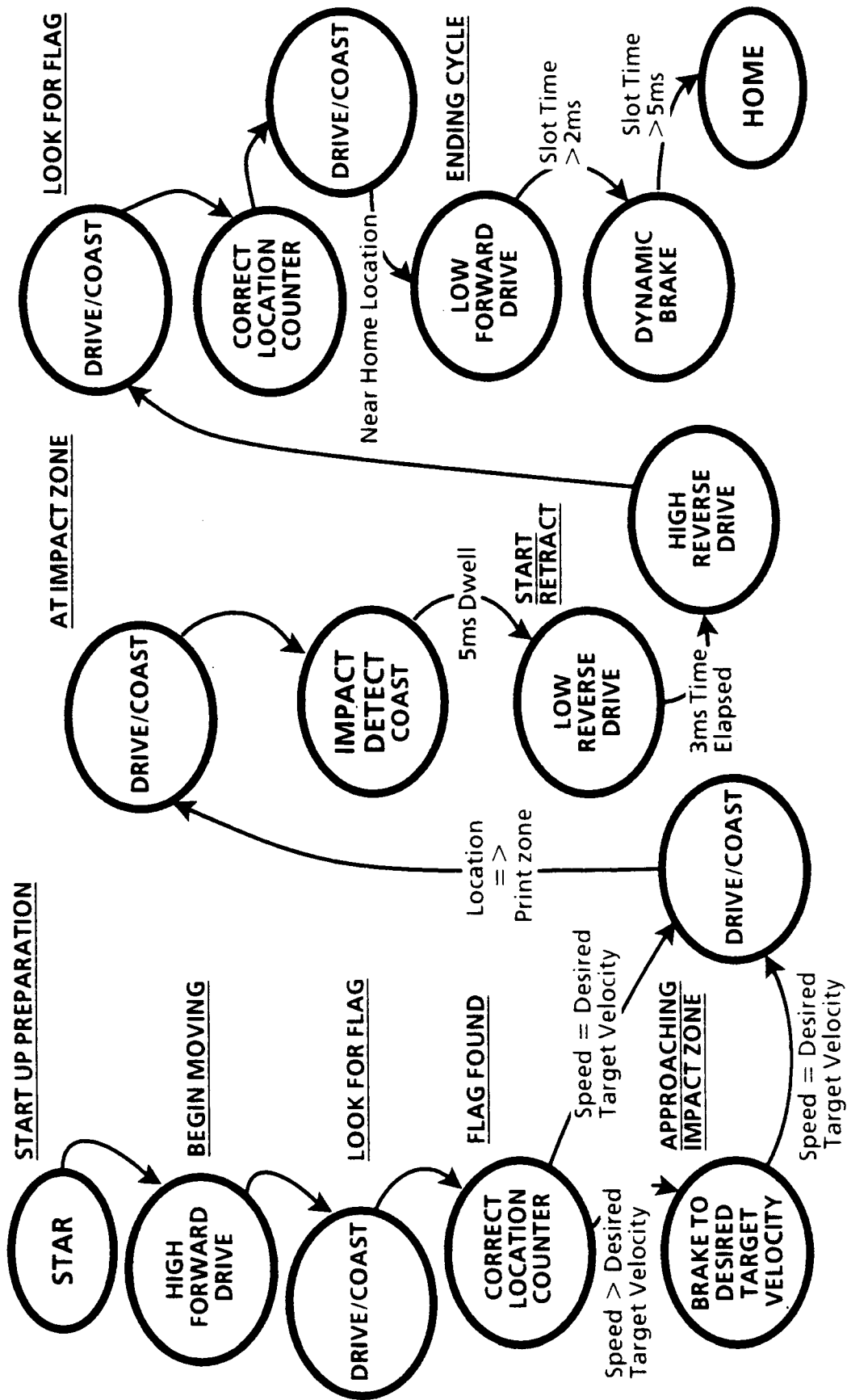


Fig. 7