Jan. 31, 1967 F. H. SHEPARD, JR 3,301,177

HAMMER FIRING ARRANGEMENT FOR HIGH SPEED PRINTER

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Fig. 1.

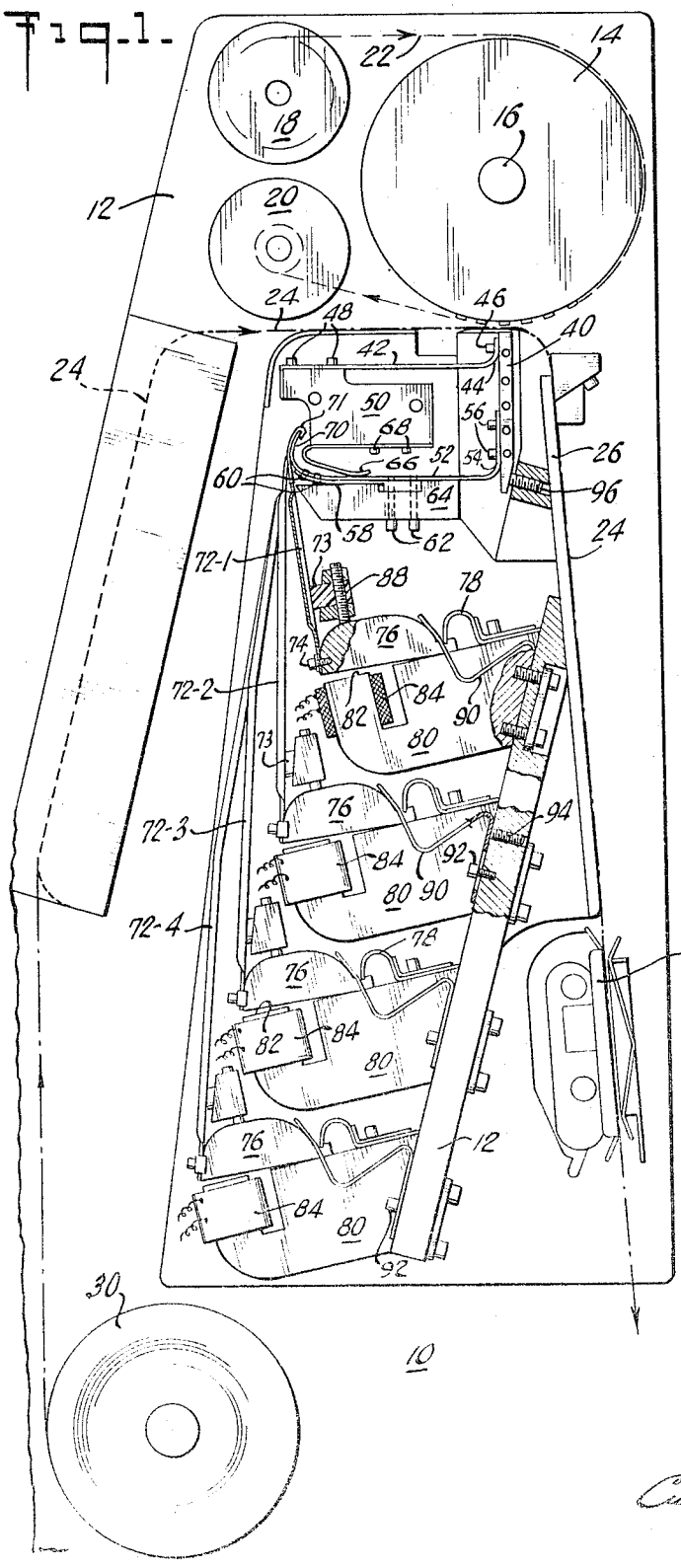
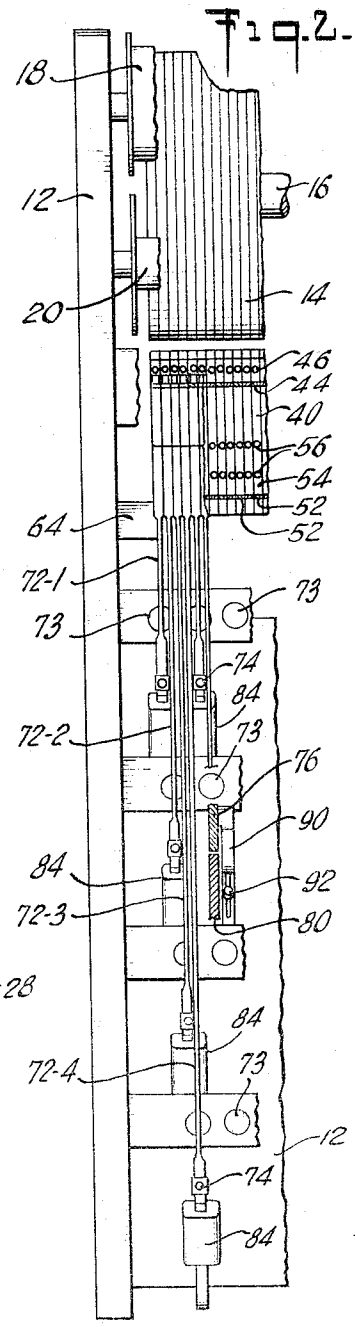


Fig. 2.



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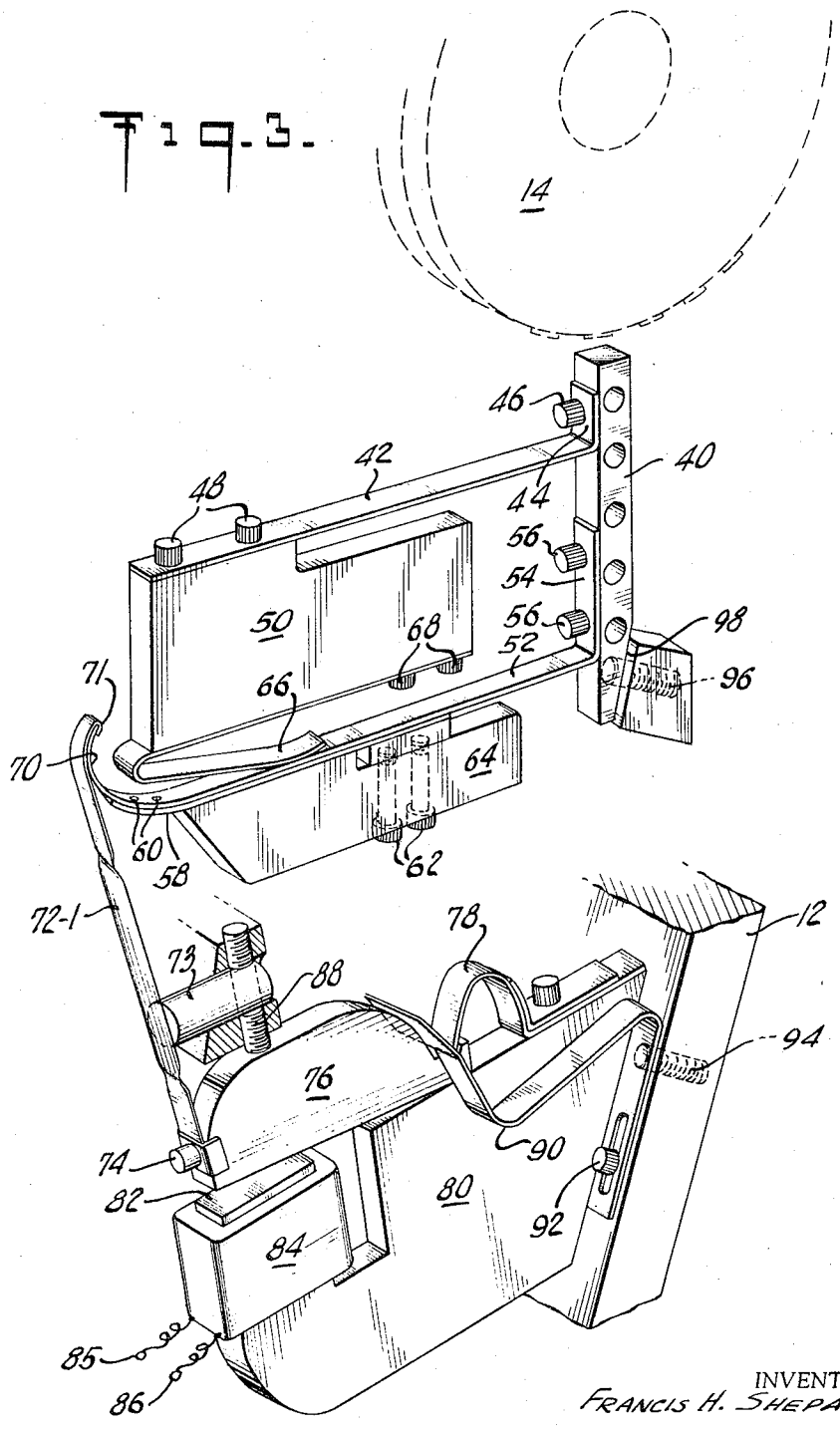
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Fig. 3.



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3,301,177

HAMMER FIRING ARRANGEMENT FOR HIGH SPEED PRINTER

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This invention relates to a high speed electro-mechanical printer, and more particularly to actuation of the type-hammers therein.

An object of this invention is to provide a way of energizing or firing the hammers in a high speed printer to give more precise control of the energy imparted to the hammers, more accurate timing of the blows of the hammers in printing, higher speed and better efficiency, all of which contribute in important respects to superior operation of a printer.

A further object is to provide an arrangement of this kind which is so efficient and reliable in its operation that it will stand up under billions of cycles of operation.

Still another object is to provide a hammer firing arrangement which is simple and inexpensive to manufacture and which is quite compact in size.

These and other objects will in part be understood from and in part pointed out in the following description.

There is described in the inventor's U.S. Patent No. 2,787,210 a high speed printer in which a strip of paper is passed through the machine and printed upon line-by-line. The print marks on the paper are made by the blows of a multitude of rod-like hammers, which are positioned in a horizontal row beneath the paper and which are fired individually. When a hammer strikes the paper, the latter is forced upward against a continuously rotating wheel on the rim of which are raised alpha-numerical characters. By synchronizing the firing of the hammer with the precise instant that a particular type character is directly above the paper, this character will make an inked impression on the paper.

Now, in order to achieve high speed operation (for example, twenty or more lines of type per second), it is necessary to fire each hammer in an extremely short time (of the order of a very few milliseconds), and then have it ready for the next printing cycle, and so on. Previously, in a hammer firing arrangement such as shown in the above-mentioned patent, a chief factor limiting the speed at which the printer could operate was the time required for the parts of the hammer firing mechanism to complete a stroke and then return to rest or equilibrium condition prior to the beginning of another hammer firing cycle. In this previous mechanism, a pivoted beam or armature is pulled upward by magnetic attraction from a solenoid above it and is thus swung in the manner of a baseball bat against the lower end of the type hammer. Since the beam has considerable inertia, there is an appreciable time delay between the instant the solenoid is first energized and the instant it strikes the hammer. Secondly, because only part of the kinetic energy in the swinging beam is imparted to the hammer, not only is overall efficiency low, but the energy remaining in the beam must be dissipated by impact against and bounce-back from the solenoid pole pieces. This striking and bouncing not only causes wear, but appreciably lengthens the time required for the beam and hammer to return to rest condition in preparation for the next hammer firing cycle.

Another disadvantage of this prior arrangement is that the precise instant of impact of hammer against paper, and hence the nicety of alignment of the finally printed characters, is dependent upon the energizing forces applied to the respective solenoids. These forces of course vary with changes in input voltage, with aging of

components of the electric supply circuits, and so forth. Thus, previously, alignment of the printing of a typer tended to be somewhat uneven. The present invention effectively reduces the dependence of hammer timing on the magnitude of energization of the solenoids within a wide range, and it substantially improves the ease of adjusting and maintaining print alignment. Further, since now each hammer blow is relatively independent of solenoid energy, the hammers strike the paper with more nearly constant force than was previously achieved. Thus the printed characters on the paper are not only very evenly aligned, but they have a highly uniform degree of "blackness" or visual depth.

In accordance with the invention, in one specific embodiment thereof, each of the hammers in a printer is mounted on a respective pair of parallel horizontal flexible canilever springs whose inner ends are attached to the frame of the machine and whose outer ends are fixed to the hammer which is mounted vertically. These springs and the hammer form a parallelogram arrangement which permits the hammer to move up and down along its axis toward and away from the paper and type wheel. The upper spring is primarily a guide or support spring and is very limber; its inner end terminates on the frame. The lower spring, however, in addition to guiding the hammer, serves to impel or "fire" the hammer against the paper in a "whip" action. The lower spring near its inner end is mounted upon the frame as upon a fulcrum, while the innermost end of this spring is connected to a pull-wire by means of which the spring is actuated when the hammer is to be fired. The pull-wire extends down to the outer end of a magnetic armature which is mounted horizontally across the poles of an electric solenoid. The inner end of the armature is fulcrumed against the frame, the outer end of the armature being normally raised slightly out of contact with the solenoid when the latter is turned off.

When the solenoid is energized, it pulls the armature down. Now, at the first instant of energization, the gap between the outer end of the armature and the opposing pole piece of the solenoid is at a maximum (only about $\frac{1}{10}$ inch) and hence the magnetic force is minimum. However, the inertia of the armature itself, and of the pull-wire are low, and therefore these elements immediately and quickly are accelerated downward. During this initial travel, the action is so fast that the inner end of the lower spring is pulled down whereas the outer end, on which the hammer is mounted, tends not move at all because of the inertia of the hammer. Thus the lower spring is laterally flexed. One effect of the flexing spring is to pull the tail of the hammer laterally away from the stop. Another effect of this flexing is to decouple the inertia of the hamer from that of the initially moving elements of the system. As a consequence, the motion of the armature toward the solenoid pole piece is much more rapid than if the hammer also had to move at this interval. Thus the armature here is able to receive a given amount of energy (force$\times$distance) in a shorter time than would be possible if the lower spring arm could not flex. This in turn means that the solenoid here is appreciably more efficient for a given amount of energy which must finally be imparted to the hammer; this solenoid needs less than half the electrical energy which had to be supplied in the old arrangement. Thus the solenoid can be smaller in size and cheaper in construction, and the electrical circuit which supplies it can be less powerful.

A second result of the spring-flexing action in this new arrangement is that as the armature moves nearer to the solenoid pole piece, the non-linearly increasing magnetic pull on the armature is offset by greater and greater

resistance from the bending spring around a shifting fulcrum. Thus, the armature at the end of its travel, rather than slamming against the pole piece and thereby wasting a considerable amount of energy, instead comes against the pole piece with greatly reduced velocity. In effect, the energy imparted to the armature is almost entirely transferred to the flexed lower spring. This means a further increase in overall efficiency and, together with other design features, a great reduction in wear of the parts and of the time required for them to return to equilibrium in readiness for the next firing cycle.

The bending force of the lower spring is designed in relation to the inertia of the hammer and the dynamic forces exerted by the armature and pull-wire so that the spring can store and then transfer to the hammer the great majority of the energy imparted to the armature. Thus, the spring in effect is fully cocked (as though the hammer had been held) and thereafter "whips" the hammer upward. Since only the weight of the hammer must now be moved, it can be accelerated much more quickly; the energy stored in the flexed spring will be almost 100% transferred to the hammer. The latter then flies up as though it were a free body and drives the paper (together with an inked ribbon) against a desired type character. After printing a letter, the hammer drops back down to its starting position. The hammer is returned primarily by rebound but partly by the two spring arms guiding it. A special wedge-shaped stop on the frame behind the hammer absorbs the impact of the hammer on its back stroke and eliminates undesired vibrations. Thus the hammer and solenoid are immediately readied for the next firing cycle. The overall time for one firing cycle, such as described above, is very short being of the order of about 7 milliseconds (0.007 sec.) as compared with about 30 milliseconds required in the previous arrangement.

As was mentioned above, this new arrangement makes the timing of a hammer blow virtually independent (within a wide range) of the amount of electric energy supplied to the solenoid. In one specific unit which has been built and satisfactorily operated, the time required for the armature to close against the pole piece was about two milliseconds, whereas the time required for the cocked spring to whip the hammer up and fully transfer its energy to the hammer is about 4 milliseconds. Though the closing time of the armature is to some degree lengthened or shortened by the amount of magnetic force exerted by the solenoid, variation in this time will nonetheless be only a small portion of the total time cycle. The time for the cocked spring to transfer its energy to the hammer, on the other hand, is relatively independent of armature closing time and is determined by the resonant frequency of the spring and hammer. Thus the spring time, once set at the factory, will be highly constant, and hammer-firing time will in turn be essentially constant.

In this new arrangement, impact time of each hammer is minutely adjustable mechanically by varying the force of a spring acting on the armature counter to the pull exerted by the lower hammer spring. Thus, given normally constant timing of the electric circuits of the various solenoids, the respective hammers can be adjusted mechanically for perfectly aligned printing. Once adjusted, they will stay in adjustment.

During manufacture of the hammer and solenoid assemblies, the discharge time of each lower spring is adjusted to be substantially equal to a given value (e.g. 2.5 ms.). This is accomplished by energizing each solenoid (with its armature held by a piece of rubber away from its pole piece) with an electric current, the frequency of which is varied until the hammer oscillates with maximum amplitude. Then by adjusting the stiffness of the lower spring, the resonant frequency (e.g. 100 cycles per second) of each assembly is trimmed to coincide with the desired value. Since all assemblies thereafter have the same resonant frequency, their spring times will be identical.

As was mentioned above, a hammer and lower spring are connected to an armature by a pull-wire. Using pull-wires of different lengths for adjacent assemblies, it is possible to stagger the relatively thick solenoids in a stair-step array and thus easily obtain spacing of the hammers determined solely by their thickness and not that of the solenoids. Spacings of ten to the inch are readily obtainable.

In this new arrangement, there are no pivot pins (which are notorious wear points), and each solenoid, armature, pull-wire, spring, and hammer are exceedingly rugged in construction. To the naked eye, the lower spring, which in fact flexes and whips the hammer, looks like a stiff arm of metal fulcrumed to the frame. The hammers stay in exact alignment in the frame because of the guiding and supporting action of the upper and lower springs; there is no need of precision guideways, which means not only reduced wear but less cost and better action.

A better understanding of the invention will best be gained from the following description given in connection with the accompanying drawings wherein:

FIGURE 1 is a side view of a table model printer showing in general detail the type wheels and paper feed and in greater detail the hammer firing arrangement which embodies the invention,

FIGURE 2 is a partial front view of the printer showing the staggered arrangement of the hammer firing solenoids, and

FIGURE 3 is an enlarged perspective view of one of the hammer firing solenoids and its associated hammer.

The printer **10** shown in FIGURE 1 comprises an upstanding frame **12** on which is journaled a horizontal typewheel drum **14**. The latter comprises a stack of individual type wheels mounted on a horizontal axle **16**, the drum being continuously rotated at high speed (i.e. 1200 revolutions per minute) by a motor (not shown) when the printer is in operation. To the left of the type drum are a pair of rollers **18** and **20** on which is wound an inked ribbon **22**. This ribbon passes from roller **18** around and under the type drum and onto roller **20**. Rollers **18** and **20** are driven in one direction, then the other to feed the ribbon slowly and continuously past the type drum. Passing immediately beneath the ribbon and tangential to the type drum is a strip of paper **24** which is guided over a generally horizontal plate **26** and pulled down the front of the machine by means of a tractor **28** which engages perforations in the edges of the paper. The paper is drawn a line at a time at high speed (e.g. 20 lines per second) beneath the type drum, being supplied from a roll **30** at the lower rear of the machine, or from a paper tray when fanfold paper is used.

Mounted vertically beneath the type drum is a horizontal row of closely spaced type hammers **40**. Each of the hammers is identical to the others and at rest their upper, or striking ends, lie slightly below paper **24**. When a hammer is fired, it will drive the paper and ribbon against any selected character around the rim of drum **14** and thereby print the character on the paper.

Each hammer **40**, see also FIGURE 3, is supported by a top spring **42** whose front end is bent over at **44** and fastened by means of a small screw **46** to the hammer. The rear end of the spring is attached by a pair of screws **48** to a horizontal bar **50** which is integral with the frame of the machine. The lower end of hammer **40** is attached to a lower spring **52** whose forward end **54** is bent over and fastened to the hammer by screws **56**. Spring **52** is mounted generally parallel to upper spring **42**. Beneath the center section of the lower spring is a somewhat curved springy cantilever arm **58** which at the left is riveted to the spring at **60** and at the right is fastened by screws **62** to a lower horizontal bar **64** integral with the frame of the machine. Arm **58** provides a flexible rocker

surface for spring **52**. The spring is pressed downward against arm **58** by a curled-over leaf spring **66** wedged between the spring and the underside of bar **50**, spring **66** being attached to the latter by screws **68**. The rear end of lower spring **52** extends beyond bar **64** and has an upwardly bent portion **70**. Hooked to each spring end at **71** is a respective one of the four pull-wires **72–1**, **72–2**, **72–3** and **72–4**. Each of these has a different length, and though all extend downward, they lie at different angles with respect to a vertical line. Except for this difference in the pull-wires, the four hammer firing assemblies are identical. As was mentioned previously, the use of different length pull-wires permits the electric solenoids which energize the hammers to be staggered so that the spacing of the hammers is limited only by the thickness of the hammers and not by the somewhat greater thickness of the solenoids. A sequence of four different pull-wires in the embodiment illustrated permits the necessary staggering of the solenoids; this sequence can be repeated as many times as required to provide for all of the hammers in a printer. If thicker solenoids are used, a larger number of different pull-wires will be needed, and for thinner solenoids, fewer different pull-wires. As seen in FIGURE 3, pull-wire **72–1** has a flattened upper end, a flattened lower end and a channel-shaped center portion. This construction gives light weight yet minimizes the tendency of the pull-wires to vibrate laterally as an ordinary piano-wire would do. Near the lower end of each wire is an adjustable plastic damping member **73** which rubs lightly against it to minimize vibrations. Additional plastic dampers (not shown) may bear against the opposite side of the pull-wires.

The lower end of each pull-wire is attached by a screw **74** to the outer end of a respective magnetic armature **76** whose inner end is clamped by a spring clip **78** against a magnetic solenoid piece **80** screwed to the frame of the machine. The heel of armature **76** which bears against solenoid **80** beneath clip **78** is curved so that the left or outer end of armature **76** in the at-rest position shown rocks up and is separated by a small air gap from a pole piece **82** of solenoid **80**. Pole piece **82** is surrounded by a solenoid coil **84** having input terminals **85** and **86** to which a pulse of current is applied at the appropriate instant for energizing the type hammer. A suitable supply circuit is shown in the inventor's U.S. Patent 2,997,632. The at-rest position of armature **76** is determined by a set screw **88** bearing against its top and projecting from a portion of the frame.

When coil **84** is energized, armature **76** will be pulled down flush against pole piece **82**. This movement will cock lower hammer spring **52** and thereafter fire the hammer upward against the paper, as explained above. Since no pivot pin is used to support the armature or spring **52**, wear is effectively eliminated.

At the first instant solenoid **80** is energized, armature **76** will be attracted toward pole piece **82** with a relatively small pull since the air gap between them is maximum. However, at this instant, when hammer spring arm **52** is unfluxed, the forces opposing movement of armature **76** are at their minimum. But as the armature moves closer and closer to pole piece **82**, and the magnetic force of attraction gets larger and larger, the counter force on the armature transmitted by pull-wire **72–1**, and exerted by spring arm **52** as it begins to flex and to rock on curved member **58** (thus changing its fulcrum point), increases. This changing counterforce of the spring is matched to the changing magnetic pull of the solenoid by choosing a given curvature and position of member **58** and a given stiffness of spring-arm **52**. Thus there is obtained an impedance match between the energy system of the solenoid and that of the spring-arm. As a consequence a greater amount of energy in a shorter time can be dumped into the cocking of the spring-arm (and thence into the hammer) by the solenoid than is possible in the arrangement shown in Patent No. 2,787,210 mentioned previously.

This in turn means that the present system is more efficient and that for a given amount of energy, higher hammer velocity is achieved. Because the hammer here can be impelled with higher velocity, a lighter one can be used and still obtain the same momentum and force of impact. All of these factors give important operating advantages, such as better type print impressions on multiple copy paper, faster operation, and better print alignment. Of course, the present system still uses the basic invention of the prior patent.

As seen best in FIGURE 3, armature **76** has bearing down against its upper rear face, the outer end of a long, curved spring **90** whose right end is fastened to the frame by a screw **92**. The pressure exerted by spring **90** is counter to the force of spring clip **87** and the pull of pull-wire **72–1**. The pressure of spring **90** is adjustable by means of a set screw **94** projecting against its rear face. Now, by adjusting spring **90**, very accurate, constant timing of the blow of hammer **40** is obtained without changing the rest position of armature **76** or of hammer **40**. Adjusting spring **90** changes the instant at which armature **76** begins to move after coil **84** has been energized, but does not appreciably effect the total time for the armature to close or the energy put into it in closing. The rest position of hammer **40** is determined by a nylon adjusting screw **96** which projects through a portion of the frame and bears against a slanted wedge surface **98** at the rear end of the hammer. Appreciable changes in the rest position of the hammer do not affect the timing of a hammer blow, and in practice screw **96** is adjusted after screws **88** and **94** have been set. Screw **96**, in conjunction with wedge surface **98**, serves the important function of immediately absorbing and damping out vibrations in the hammer when it rebounds from a blow against the paper and type drum. The angle of surface **98** with respect to the vertical axis of the hammer is approximately 10° and is chosen to give a wedging action of the hammer against screw **96**. When the hammer rebounds from a blow, it will strike against screw **96** without bouncing. This immediately damps out vibrations and readies the hammer for the next firing cycle. Without this damping arrangement, the total cycle time, allowing for all parts to return to rest, would be considerably longer.

By adjusting the stiffness of lower spring **52** to a greater or less degree, the resonant frequency of the hammer assembly (and the firing time of the spring **52**) can be adjusted to a desired value, as mentioned above. To measure this, a piece of rubber is placed between armature **76** and pole piece **82** to hold the armature away from the pole piece, but still permit it to vibrate at the frequency of the test current being applied to coil **84**.

In an actual printer which has been built and successfully operated, each hammer can be fired over 100 times per second. The time required for an armature **76** to close against pole piece **82** is about 2 milliseconds. The time required for lower spring **52** to transfer its energy to hammer **40** (flight time of the hammer) is about 2.5 milliseconds. The flight distance of the hammer is about $\frac{1}{10}$ inch. Each hammer is about 2 inches long. A current of 5 amperes for three milliseconds applied to coil **84** energizes the hammer. Each hammer assembly is adjusted so that the top of the hammer is just barely separated from type drum **14** when armature **76** is held (steady state) against pole piece **82**. Springs **42** and **52** are made of beryllium copper. It is important in order to eliminate metal fatigue that these members have no sharp bends or stress points. Shaping them as shown helps eliminate this danger. Spring **52**, where it bends up to portion **54**, is thinned down to make it more flexible at the bend and eliminate metal fatigue. The parts of the hammer and solenoid assemblies of this printer are shown substantially to scale in FIGURES 1, 2 and 3. Armature **76** and solenoid **80** are solid metal slugs; it is not essential to laminate them.

The above description is intended in illustration and not in limitation of the invention. Various changes or modifications in the embodiment set forth may occur to those skilled in the art, and may be made without departing from the spirit or scope of the invention as set forth.

I claim:

1. A hammer firing assembly of the character described comprising, a machine frame, an elongated hammer, means to guide said hammer in said frame, and a firing spring cantilever arm engaged at one of its ends with said hammer and adjacent its other end pivoted on said frame, said hammer being axially movable toward and away from a type member, and means to flex said firing spring arm to whip said hammer at high velocity toward the type member, said firing spring arm having a rocker surface bearing on said frame, said rocker surface providing a movable fulcrum for said arm when it is flexed, said arm having an outer end which overhangs said frame, said means to flex including a fixed solenoid and a movable armature, said armature bridging a gap across said solenoid, and a pull-wire attached at one end to said armature and at its other end to the outer end of said firing spring arm.

2. The assembly in claim 1 in further combination with a plurality of substantially identical assemblies, the solenoid of one assembly being staggered relative to the adjacent solenoids, the pull-wire of said one assembly being different in length from the pull-wires in adjacent assemblies.

3. The assembly in claim 1 wherein there is an adjustable spring acting on said armature counter to the other spring force on it, said adjustable spring being settable to control the timing of a hammer blow.

4. The assembly in claim 2 wherein each hammer is engaged by an energy damper in rest position.

5. The assembly in claim 2 wherein said pull wires are engaged by vibration dampers.

6. The assembly in claim 2 wherein each pull wire and spring arm is of metal and is shaped and formed to eliminate focal points for metal fatigue.

7. The assembly in claim 2 wherein each hammer and its associated springs have substantially the same resonant frequency.

8. In a high speed printer of the character described, a base member carrying a type font, at least one lightweight, elongated type hammer adapted to be fired end first at high velocity as a substantially free projectile toward said base member to print on a piece of paper and the like, electromechanical energizing means to produce a short, sharp mechanical movement on command from a control signal, and impedance matching means interconnecting said energizing means and said hammer to transfer with increased efficiency the mechanical movement of said energizing means into high velocity of said hammer, said impedance matching means including a pole-like spring arm, one part of which engages said hammer to propel it, an electromagnet spaced from said hammer and coupled to a second part of said arm, said arm having a third part pivotally secured to said base member, and means for energizing said electromagnet to permit said arm to be substantially flexed laterally to build up propelling force for the hammer to accelerate it with high velocity toward the type font.

9. In a high speed printer of the character described, a base member carrying a type font, at least one lightweight type hammer adapted to be fired with high velocity toward said base member to print on a piece of paper and the like, energizing means to give a short, sharp mechanical movement to said hammer on a command from a control signal, said energizing means including a spring member connected to said hammer to propel it, and means to quickly damp out vibrations in said hammer when it rebounds from a blow, said damping means including a slanted surface adjacent the rear of said hammer, and a stationary stop which wedges against said surface when the hammer rebounds, said spring member when said energizing means is actuated moving said slanted surface and said stop laterally apart to eliminate starting friction of said hammer.

10. In a high speed printer of the character described, a base member carrying a type font continuously movable at high speed, at least one lightweight type hammer to be fired at high velocity toward said base member to print by a blow on a piece of paper and the like, an electromagnet including a movable armature movable toward and away from said electromagnet and coupled to said hammer to give it a short, sharp mechanical movement toward said base member on command from a control signal, and timing means to adjustably set the timing of the blow of said hammer, said timing means including mechanical bias means to hold said armature against a stationary stop with a pre-set gap between armature and electromagnet, and adjustable means to set the force holding said armature against said stop whereby the timing of a hammer blow can be controlled without changing the gap between armature and electromagnet.

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