

Aug. 21, 1962

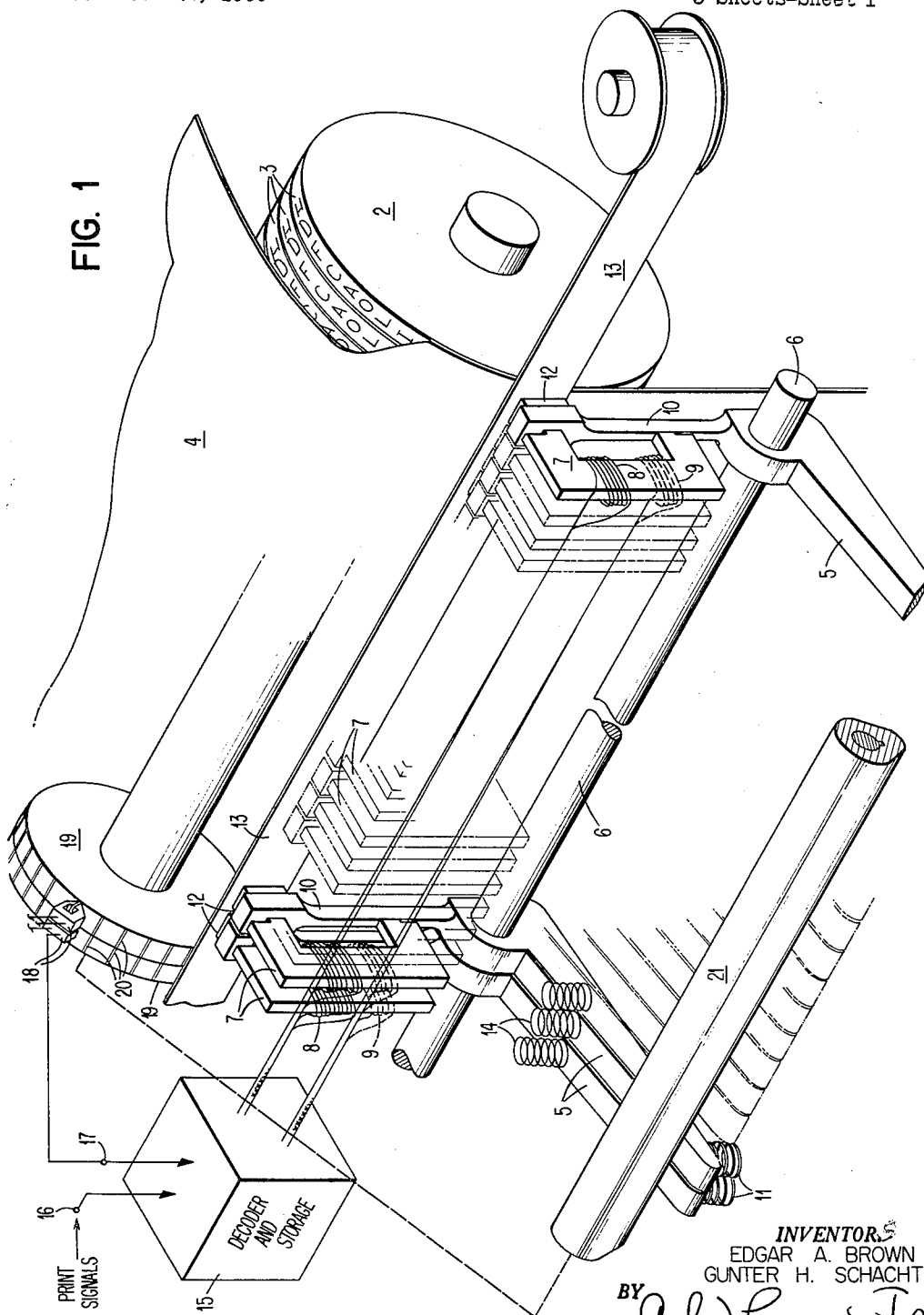
E. A. BROWN ET AL

3,049,990

PRINT HAMMER ACTUATOR

Filed Dec. 20, 1960

3 Sheets-Sheet 1



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3 Sheets-Sheet 2

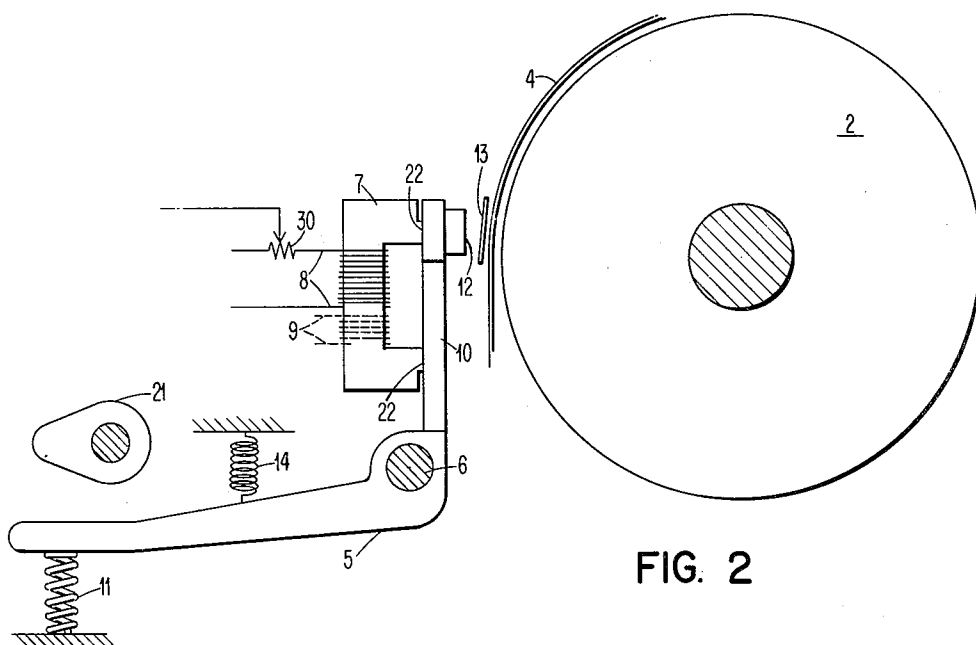


FIG. 2

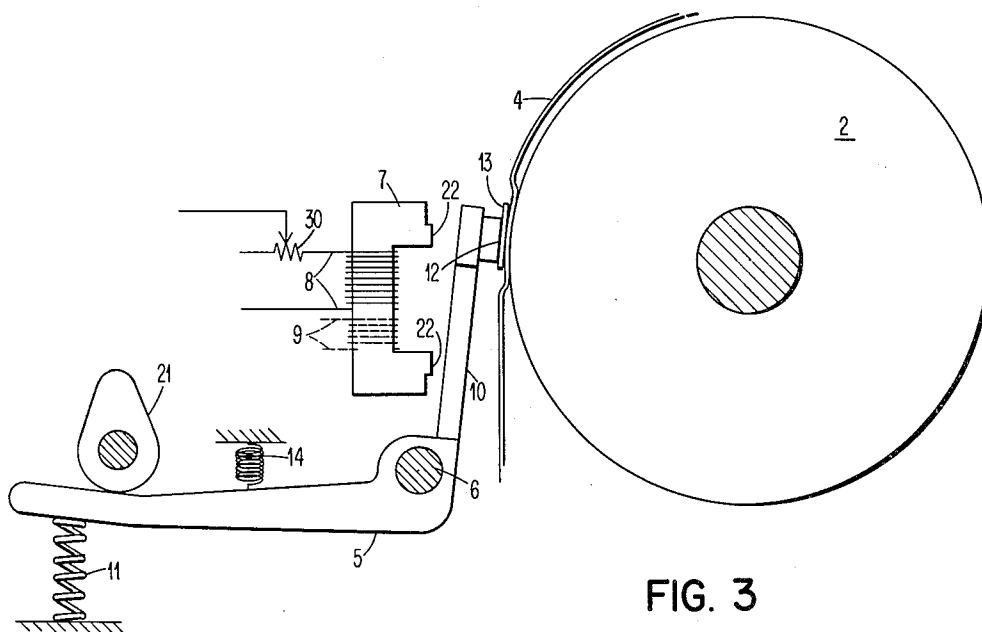


FIG. 3

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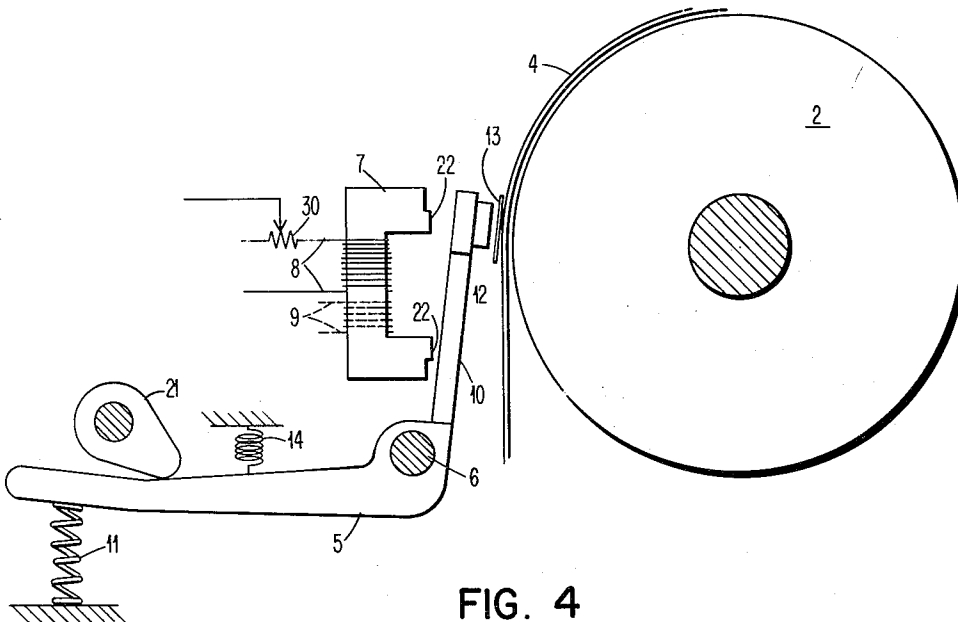


FIG. 4

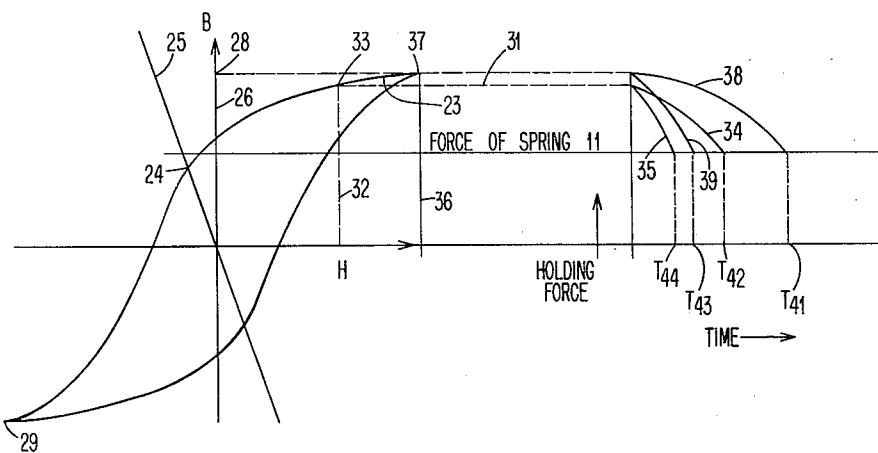


FIG. 5

FIG. 6

1

3,049,990

PRINT HAMMER ACTUATOR

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Filed Dec. 20, 1960, Ser. No. 77,135

9 Claims. (Cl. 101-93)

This invention relates generally to a high speed electromechanical actuator and in particular to an actuator for a print hammer.

High speed printers of the type using a print hammer to strike a moving type wheel require extremely rapid hammer action which must be accurately timed. The overall speed of the printer is limited by the speed and timing accuracy of the hammer movement since both of these characteristics affect the legibility and quality of the printing.

These requirements have led to the development of electromechanical actuators for print hammers. Various forms of such actuators exist in the prior art. Typically, such devices have been operated by magnetically attracting an armature to a core, and transferring this movement to a print hammer. This motion produces the print operation. When the magnet is de-energized, the armature is moved away from the core by a bias spring to prepare the hammer for another cycle of operation.

The relatively strong electromagnet required for this type of operation is a disadvantage since the heat dissipated limits the duty cycle of the device. Furthermore, the current drawn by the electromagnet is affected by heat-induced changes in winding resistance. The obvious consequence of these current variations is poor reproducibility caused by changes in attractive force which affect the actuating time of the device.

In devices which move an armature toward a core through electromagnetic attraction, the initial force is relatively small due to the air gap between the core and armature. With only a small attractive force available to overcome static friction the initial movement of the armature tends to be erratic, resulting in poor reproducibility. Since static friction is a primary cause of erratic operation, it is desirable to have the maximum force available at the beginning of movement so that friction is quickly overcome. A working magnet is therefore a poor approach to the problem of overcoming static friction since its attractive force is the least powerful when it is most needed.

We have found that a greatly improved actuator results from a device wherein the armature is restored to a position abutting the core by mechanical means and held there against the action of a bias spring by the force of magnetic attraction. The print operation is accomplished by reducing the magnetic flux to the point where it no longer holds the armature against the action of the bias spring, allowing the spring biased armature to move the print hammer very rapidly. By using the magnet only to hold the armature the size of the magnet and the current requirements can be greatly reduced. Elimination of the heat dissipation problem also helps to maintain a more constant attractive force for the electromagnet so that the release time is essentially unvarying.

Our preferred embodiment uses a powerful spring to rapidly accelerate the armature which has a flux path sufficient to permit the spring to be contained by the force of magnetic attraction. This could provide a marginal differential between the residual induction and the dropout value of the device with the chance that the armature might fail to release properly when the mag-

2

net is de-energized. To prevent such failure, our invention uses a bucking coil energized in opposition to the magnet to decrease the flux to a value below the residual induction. This coil is wound with relatively few turns to present a low inductance to the driver which permits a rapidly changing high current pulse to be applied to the coil. The opposing flux of this coil causes a rapid reduction of the flux in the core and armature to the point where the armature is released for movement by the spring. The use of a bucking coil, in addition to making the device more reliable, provides another advantage by increasing the speed of response. Since the opposing or bucking coil is not continuously energized but only pulsed, the problem of excessive heat dissipation is eliminated. With the use of a bucking coil variations of release time due to temperature changes of the device are kept to a minimum since the resistance and hence the current in both the holding and releasing coil will be similarly affected and therefore compensate for each other.

It is therefore an object of our invention to provide an improved print hammer actuator.

Another object of our invention is to provide an electromagnetic print hammer actuator using a mechanical restore and a "no work" magnet.

It is another object of our invention to provide an actuator for a print hammer in which release of the hammer is achieved by a reversal of the net magnetic flux in a "no work" magnet.

Still another object of our invention is to provide a print hammer actuator for a printer in which the actuating time may be easily adjusted.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of the preferred embodiment of the invention, as illustrated in the accompanying drawings.

FIG. 1 is an isometric view, with parts cut away and portions shown in schematic form, of a drum printer embodying the invention.

FIG. 2 is a sectional view of the drum printer in FIG. 1 showing the print hammer in the ready position.

FIG. 3 is a sectional view similar to FIG. 2 but showing the print hammer in the print position.

FIG. 4 is a sectional view similar to FIG. 2 but showing the print hammer after printing and before it is restored.

FIG. 5 is a B-H curve for the pole face portion of the magnetic core used in this invention.

FIG. 6 is a graph showing the holding force of the magnet as a function of time for the single coil device and also the embodiment using an opposing coil.

With reference to FIG. 1, a continuously rotating drum 2 has a plurality of type faces 3 arranged on the periphery in cylindrical bands. Each type face contains a complete alphabet and such numbers and special characters as may be required. The drum is rotated at high speed to repetitively present all characters in each face to the printing location. Since each face accommodates one print space, there are as many tracks as there are spaces in a line.

A document 4 is held in position away from the drum but adjacent thereto by suitable means not shown. After a complete line has been printed, document 4 is advanced to a position for printing of the next line. Such positioning and feed means are well known and have not been shown since they are not part of our invention.

A plurality of print hammers 5, one for each print position, are pivotally mounted on shaft 6. Some hammers have been omitted from the drawing for clarity. Magnetic means, comprising cores 7 having windings 8 and 9, are adapted to engage armature portion 10 of print

3

hammers 5. When the magnetic flux in core 7 falls below a critical, predetermined value, print hammer 5 is freed for movement toward drum 2 by the force applied through actuating spring 11.

Each of print hammers 5 have a face portion 12 which presses ribbon 13 against document 4 and the particular character of the associated face in position at that instant. This transfers the character image to the front surface of the document.

Springs 14 lightly bias the print hammers 5 away from drum 2 to prevent tearing of the document 4 after printing in each position. Springs 14 are not sufficiently strong to prevent or stop the motion of the print hammer 5 but after the kinetic energy of the hammer has been dissipated they operate to hold the hammers away from the document.

The individual hammers are released in response to print signals from the decoder 15. The print signal results from coincidence of a data signal applied to input 16 from a keyboard or other device and a timing signal applied to input 17 from transducers 18. The data signals are placed in a storage location according to the line position at which it is to be printed. Each hammer has its own location in the storage means.

The timing input applied to terminal 17 is derived from coaction of transducers 18 with timing wheel 19 which is made of magnetic material. Transducers 18 are positioned close to the periphery of timing wheel 19. As the wheel is rotated past transducers 18 the variations in flux caused by slots 20 induce signals in transducer 18. The slots may be coded to provide a unique combination of signals for each position or letter of drum 2. The output signal of transducers 18 therefore indicates the letter in position to be printed at that instant. These timing signals are compared within the decoder with the stored print signals for each print position. When the timing signal corresponds to a signal in storage, a print signal is produced to fire the proper hammer.

The print signal may operate to interrupt or reverse current through a holding coil 8 on the core associated with the appropriate print hammer or it may be used to energize a second coil 9 in opposition to holding coil 8 and thereby reduce the flux in the core to a minimum value. In the embodiment shown the print signal is applied to a bucking coil 9 which opposes the flux induced by continuously energized winding 8. This releases the hammer 5 for movement toward the print drum to produce the print operation. After each revolution of drum 2, all print hammers are restored by the action of restore cam 21 which may be driven by suitable connection to drum 2 or by separate means operable in response to selected signals from transducers 18 or decoder 15. Since the flux in core 7 is once again sufficient to hold armature 10 against the core, the print hammer is ready for another print operation.

In FIG. 2 print hammer 5 is shown in position against the core 7. Winding 8 is energized and winding 9 de-energized thereby providing sufficient flux in the core 7 to hold armature 10 against pole faces 22. As shown in the drawings pole faces 22 have an area which is less than the cross sectional area of the body of core 7. This allows the body of core 7 to be operated below magnetic saturation while maintaining the pole faces fully saturated for maximum efficiency. The number of turns and the current in winding 8 is such that the pole faces 22 are essentially saturated over the full range of operating tolerances. In other words, sufficient magnetomotive force is induced into the core for all operating conditions to make sure that the pole faces are always at the saturated region. Sufficient reserve excitation may be provided without materially changing the pole face flux density. Since the flux density in the pole face remains constant, the holding force will also remain constant despite variations in current through winding 8.

In FIG. 3 the flux in core 7 has been reduced to the

4

point where it is no longer sufficient to retain armature 10 of print hammer 5. Spring 11 then urges the print hammer forward so that face 12 presses ribbon 13 against document 4 to transfer a character on drum 2 to the document. This is the print position.

As mentioned previously, this release may be accomplished by interrupting the current to winding 8, reversing the current in winding 8, or in the preferred embodiment by energizing bucking winding 9. Although the response time of our preferred embodiment is in the order of microseconds, the linear velocity of the type track is also quite high, being approximately 300 inches per second. It is therefore necessary to develop the print signal somewhat in advance of the time it is desired to cause printing to occur. This is easily accomplished by locating the transducers 18 at the proper position.

The spring 14 has partially restored the print hammer 5 in FIG. 4. The print hammer is held away from the document 4 and ribbon 13 to prevent tearing by rotation of the drum when the document is advanced. In other words, a static balance of the force exerted by spring 11 and the force exerted by spring 14 leaves the print hammer 5 in the position of FIG. 4.

Cam 21 is rotated to restore the print hammer to the ready position. The shape of cam 21 is such that armature 10 is moved to a position abutting pole faces 22. Since coil 8 is energized and coil 9 is de-energized the armature 10 will be retained against the pole faces 22 by the force of magnetic attraction when cam 21 has rotated beyond contact with print hammer 5. The hammer 5 is now ready for another print operation.

The hysteresis loop shown in FIG. 5 represents magnetic conditions at the pole faces 22. When the holding coil 8 is energized the pole faces of core 7 are in the region of saturation, for example point 23. When coil 8 is de-energized the remanent flux decays to point 24 on line 25. Line 25 is displaced from the normal axis 26 because of the magnetic field across the air gap between armature 5 and core 7. The holding force provided by the remanent flux must be less than the force of spring 11 or the armature 10 will not release. Furthermore, the holding force provided by the saturated pole faces 22 must be greater than the force of spring 11 or the armature 10 will not be retained. Since the magnetic attraction on armature 10 is proportional to the flux density at the pole faces 22 it can be seen that the force exerted by spring 11 must lie within the range between points 24 and 28. If reliable operation is to be obtained it must be certain that the armature will not be released inadvertently. To meet this requirement the operating point is chosen so that the force of spring 11 is at least, but not necessarily more than, sufficient to cause release of the armature when winding 8 is de-energized.

This overcomes the possibility that the armature may be inadvertently released but the chance of the armature failing to release is increased. To guard against this eventuality, a second winding 9 on core 7 is energized by the print signal in a direction to produce an opposing flux to that of winding 8. This opposing flux drives the pole faces of core 7 in the direction of negative saturation, which is point 29, thereby reducing the remanent flux and also the holding force, toward zero. This insures that the armature will be released, since if the opposing flux induced by coil 9 is sufficiently large, the holding force acting on armature 10 will momentarily approach zero.

While the addition of winding 9 has been proposed to overcome the problem where the armature 10 fails to release, certain other advantages also result. For example, in a device having a very rapid response, the remanent flux in the core must be reduced to a low value for only as much time as is required to move the armature away from the core. If the armature can be moved rapidly, winding 9 may be pulsed with a current of very short duration. It has been found that it is

unnecessary to de-energize the winding 8 since winding 9 may be supplied with a high current pulse which causes the flux density to approach zero, thereby insuring that the armature will be released.

Another advantage of winding 9 is the compensation of the effects due to temperature changes, as mentioned previously.

A frequently encountered problem with "on the fly" printers is registration. Since the type is moving at high speed any lack of proper hammer timing results in displacement of the printed character from the proper position. In this embodiment any error in registration is limited to vertical displacement since the horizontal position is fixed. Although our device achieves greater accuracy than other systems of comparable speed, it is desirable that maximum speed be obtained. Small variations from hammer to hammer in response time and operating characteristics become significant factors at high speeds. To permit accommodation of these variations we provide variable resistors 30 in series with each of windings 8. While these resistors do not affect the holding force of the pole faces 22, since these are at saturation, they do affect the time it takes the current in the bucking coil to cause release. It can be seen that the operating point on the B-H curve will be further to the left for an increasing value of resistor 30 and further to the right for a smaller value. While the holding force on armature 10 remains essentially the same for all values of resistor 30, the release time may be varied over a narrow range.

This is better understood with reference to FIG. 6 and FIG. 5 in combination. Assuming that pole faces 22 become essentially saturated when the flux density reaches the level of line 31. Increased excitation to winding 30 increases the ampere turns but the flux density is increased only slightly. If resistor 30 is set to provide ampere turns equal to line 32 of FIG. 5, the flux in the core will be at point 33. Carrying this value across to FIG. 6, which represents holding force plotted against time, it may be seen that the flux decays along curve 34 when winding 8 is disconnected. A vastly faster decay is produced when winding 9 is energized with a high current pulse as shown by curve 35.

If resistor 30 is decreased to provide ampere turns equivalent to line 36, the flux will be at point 37. Carrying this value to FIG. 6, the flux decay will follow curve 38 for the case where winding 8 is merely de-energized and curve 39 for the embodiment where winding 9 is energized with a high current pulse.

Since the spring force causes the armature to be released when the flux drops below the value represented by line 40, T_{41} represents the release time for the curve 38 and T_{42} represents the release time for curve 34. The difference between T_{41} and T_{42} represents the adjustment possible with resistor 30. Similarly T_{43} and T_{44} represent the release times for flux decay curves 39 and 35 respectively.

FIG. 6, in addition to showing how the actuating time may be controlled by resistor 30, shows how the release or actuating time and the variation in this time is substantially reduced by the use of a bucking winding. The interval between T_{43} and T_{44} is substantially less than the interval between T_{41} and T_{42} . This shows the reduced influence of variables on the preferred embodiment of our invention.

The use of resistor 30 permits the operator to make an immediate accurate adjustment to correct any misalignment that may exist.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. In a print hammer actuating device: a core of magnetic material having first and second windings thereon, a print hammer having an armature portion and movable between said core and print position, spring means urging said hammer toward said print position, mechanical means for restoring said hammer to said core against the action of said spring means, means for continuously energizing said first winding to retain said restored hammer in engagement with said core, and means for momentarily energizing said second winding to oppose the flux induced by said first winding and reduce the flux density of said core whereby said hammer is released to be moved toward said print position by the action of said spring means.

2. In a print hammer actuating device: a core of magnetic material having first and second windings thereon, means for continuously energizing said first winding, a print hammer movable between a ready and a print position, an armature portion of said print hammer abutting said core in said ready position, spring means urging said hammer toward said print position, mechanical means for periodically restoring said hammer to said ready position against the action of said spring means whereby said hammer is retained in engagement with said core by the induced flux of said first winding, and means for momentarily energizing said second winding to induce a flux in said core opposing that of said first winding and to reduce the flux density of said core and release said hammer for movement toward said print position by the action of said spring means.

3. A print hammer actuator comprising: a core of magnetic material having first and second windings thereon, a print hammer having an armature portion and movable between a first, ready, position wherein said armature abuts said core and second, print, position; spring means urging said hammer toward said print position, mechanical means for restoring said hammer to said ready position against the action of said spring means, means for continuously energizing said first winding to retain said restored hammer in the ready position with said armature abutting said core, and means for momentarily energizing said second winding to reduce the flux density of said core whereby said hammer is released for movement toward said print position by the action of said spring means.

4. A print hammer actuator comprising: a core of magnetic material having first and second windings thereon wound in opposing relationship, a print hammer having an armature portion and movable between a ready position and a print position, means fixedly positioning said core to abut said armature when said hammer is in the ready position, spring means urging said hammer toward said print position, mechanical means for restoring said hammer to the ready position against the action of said spring means, means for continuously energizing said first winding to retain said restored hammer in the ready position with said armature abutting said core, and means for momentarily energizing said second winding to induce an opposing flux and reduce the flux density of said core whereby said hammer is released for movement toward said print position by the action of said spring means.

5. In a print hammer actuating device: a core of magnetic material having a winding thereon, pole face portions of said core, said pole face portions having a restricted area operating to increase the flux density in said pole face over the flux density in the remainder of the core, a print hammer having an armature portion and movable between a first position abutting said pole faces and a second, print, position; spring means urging said hammer toward said print position, mechanical means for restoring said hammer to said pole faces against the action of said spring means, means for continuously energizing said first winding to retain said restored hammer in engagement with said pole faces, and means for momentarily reducing the flux in said core whereby said hammer is released to be moved toward said print position by the action of said spring means.

7

6. A device according to claim 11 wherein the means for reducing the flux in said core comprises means for momentarily de-energizing said winding.

7. In a print hammer actuating device: a core of magnetic material having a winding thereon, pole face portions of said core, said pole face portions having a restricted area operating to increase the flux density of said pole faces over the flux density in the remainder of said core, a print hammer having an armature portion and movable between a first position abutting said pole faces and a second, print, position; mechanical means for restoring said hammer to said pole faces against the action of said spring means, means for continuously energizing said first winding to saturate said pole faces and retain said restored hammer in engagement with said pole faces, and means for momentarily de-energizing said winding to reduce the flux of said pole faces whereby said hammer is released to be moved toward said print position by the action of said spring means.

8. In a print hammer actuating device: a core of magnetic material having a winding thereon, pole face portions of said core, said pole face portions having a restricted area operating to increase the flux density of said pole faces over the flux density in the remainder of said core, a print hammer having an armature portion and movable between a first position abutting said pole faces and a second, print, position; mechanical means for restoring said hammer to said pole faces against the action of said spring means, means for continuously energizing said first winding to place said pole faces in the region of magnetic saturation and retain said restored hammer in engagement with said pole faces, means for momentarily de-energizing said winding to reduce the flux of said pole faces whereby said hammer is released to be moved toward said print position by the action of

8

said spring means, and means for adjusting the energization of said winding to vary the flux density of said core while maintaining the pole faces in the region of saturation to provide an adjustable release time without affecting the holding force of said pole faces.

9. In a print hammer actuating device: a core of magnetic material having first and second windings thereon, pole face portions of said core, said pole face portions having a restricted area operating to increase the flux density of said pole faces over the flux density in the remainder of said core, a print hammer having an armature portion and movable between a first position abutting said pole faces and a second, print, position; mechanical means for restoring said hammer to said pole faces against the action of said spring means, means for continuously energizing said first winding to place said pole faces in the region of magnetic saturation and retain said restored hammer in engagement with said pole faces, means for momentarily energizing said second winding to induce an opposing flux and reduce the flux density of said pole faces whereby said hammer is released for movement toward said print position by the action of said spring means, and means for adjusting the energization of said first winding to vary the flux density of said core while maintaining the pole faces in the region of saturation to provide an adjustable release time without affecting the holding force of said pole faces.

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