United States Patent

Howard

[15] **3,690,431**

[45] **Sept. 12, 1972**

[54] **PRINT HEAD ASSEMBLY CONTAINING SOLENOIDS**

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[73] Assignee: **Centronics Data Computer Corp.,** Hudson, N.Y.

[22] Filed: **June 14, 1971**

[21] Appl. No.: **152,598**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 37,815, May 15, 1970, abandoned.

[52] **U.S. Cl.** .....**197/1 R,** 335/274

[51] **Int. Cl.** **B41j 3/10**

[58] **Field of Search** 335/258, 274; 197/1

[56] **References Cited**

UNITED STATES PATENTS

2,390,985	12/1945	Boyer	335/274 X
2,584,707	2/1952	Jarvis et al.	335/274
2,674,652	4/1954	Johnson et al.	197/1 R X
2,853,660	9/1958	Immel	335/274 X
3,207,961	9/1965	Lohr	335/274 X
3,217,640	11/1965	Bradshaw	197/1 R X
3,333,667	8/1967	Nordin	197/1 R
3,467,232	9/1969	Paige	197/1 R
3,592,311	7/1971	Chou et al.	197/1 R

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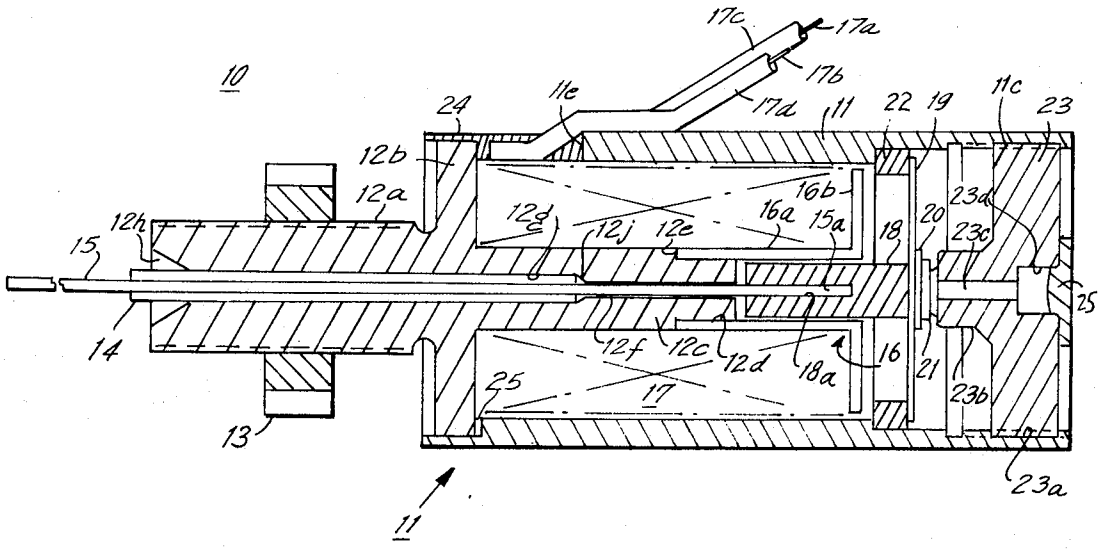
[57] **ABSTRACT**

A solenoid for actuating a print wire normally biased against the impact direction by "wagon wheel" spring means. Energization of the solenoid coil rapidly moves the print wire in the impact direction against the bias of the spring. Release of the energy supplied to the solenoid coil causes very rapid return of the print wire to the non-printing position. The "wagon wheel" spring structure, which undergoes both bending and twisting in a predetermined sequence, allows for rapid initial acceleration of the print wire in the impact direction while providing for rapid return of the print wire to the non-print position while significantly reducing "bouncing" or "overshooting".

The components of the solenoid are so designed as to greatly simplify and facilitate assembly while providing highly precise adjustment of the solenoid assembly through the use of components whose tolerances need not be tightly controlled.

6 Claims, 11 Drawing Figures



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SHEET 1 OF 3

FIG. 1

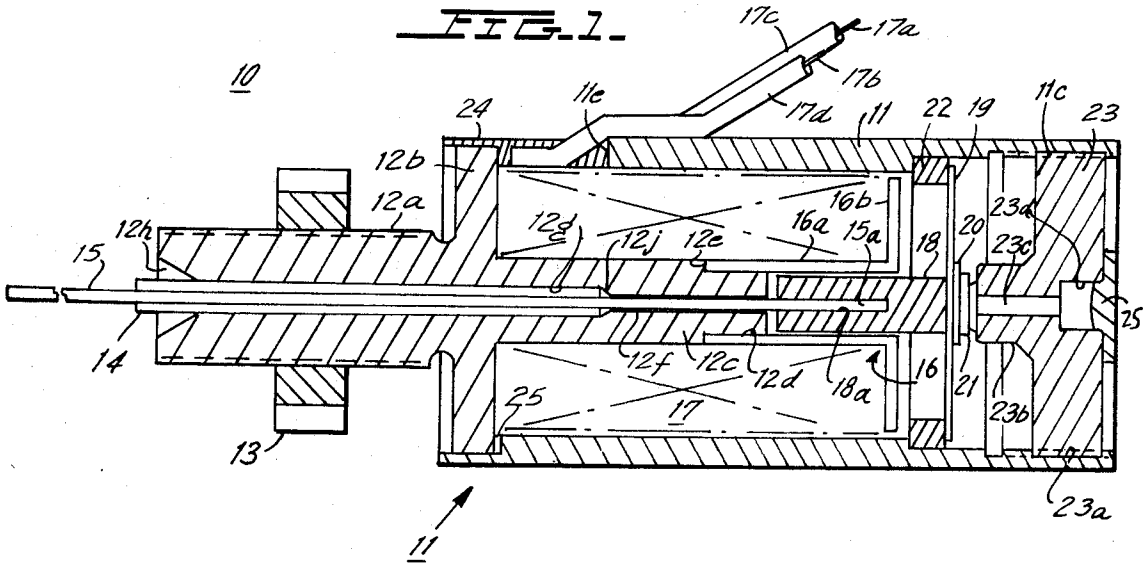


FIG. 1a

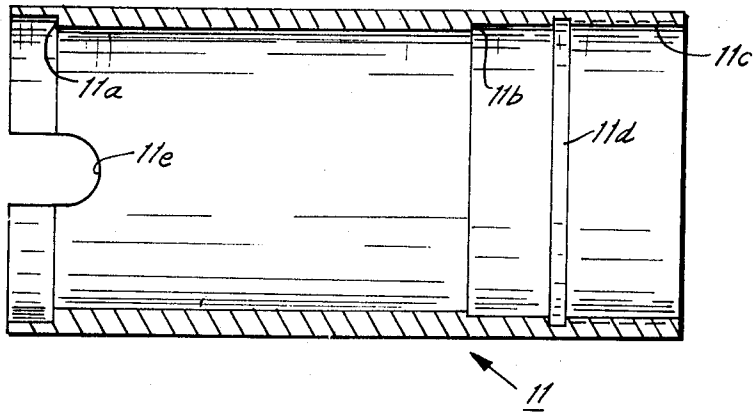


FIG. 1c

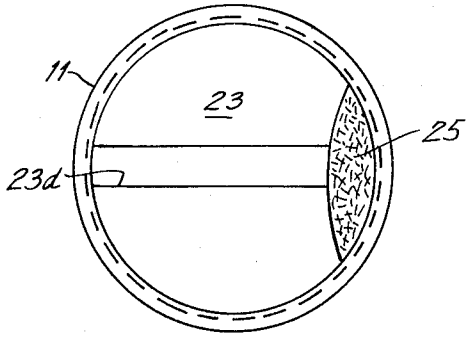
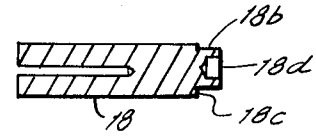


FIG. 1b



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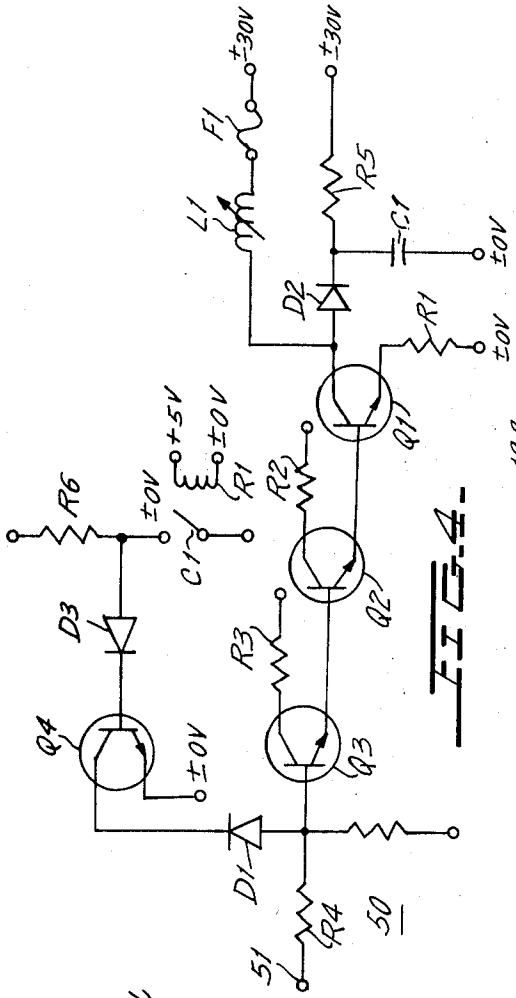

FIG. 4.

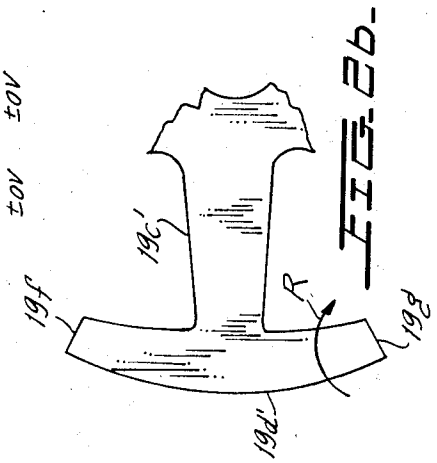

FIG. 2b.

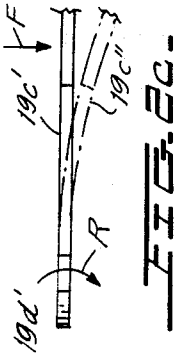

FIG. 2c.

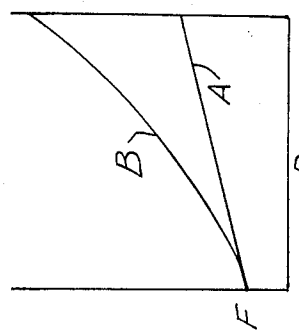

FIG. 2a.

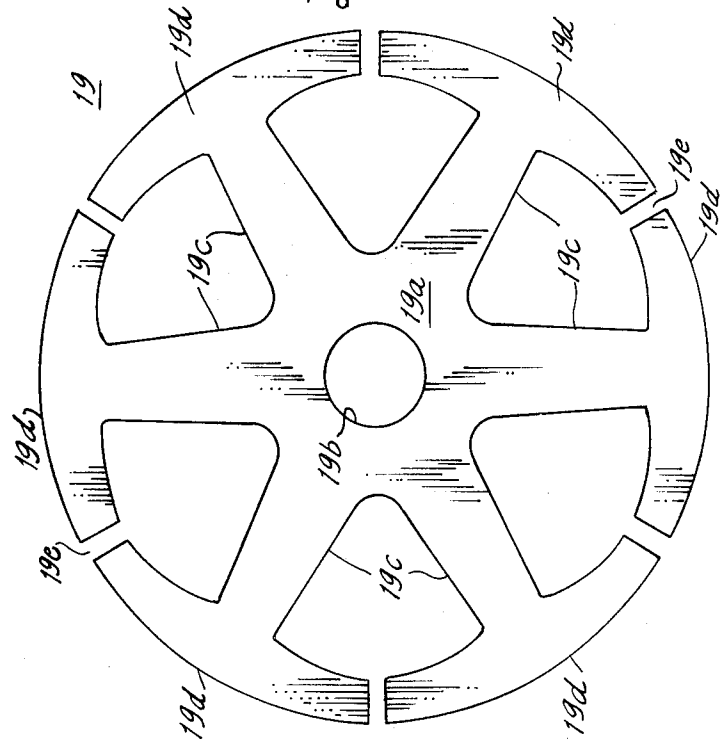

FIG. 2.

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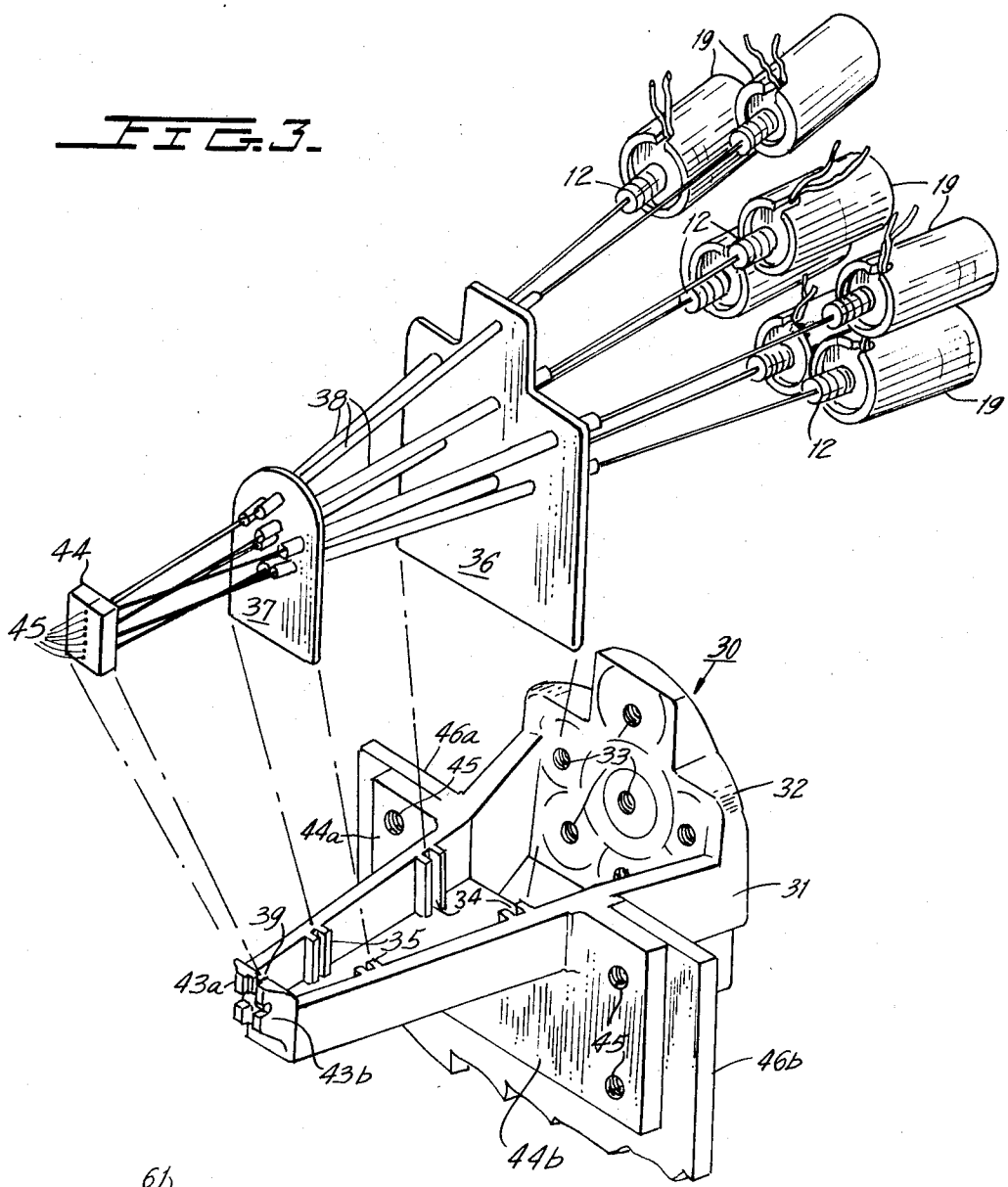
FIG. 3



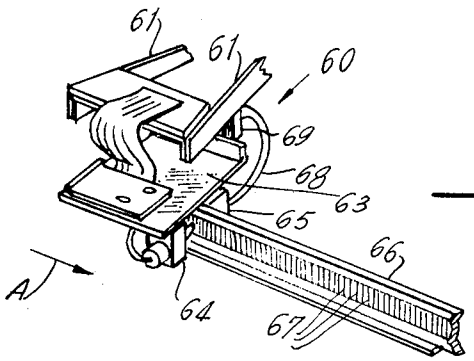


FIG. 3a

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PRINT HEAD ASSEMBLY CONTAINING SOLENOIDS

The present application is a continuation-in-part of, and an improvement upon copending application Ser. No. 37,815 filed May 15, 1970 by the present inventor, and now abandoned.

The present invention relates to solenoid assemblies and more particularly to a novel solenoid assembly especially advantageous for use in dot matrix printers and the like due to its capability of providing rapid acceleration in the impact direction and rapid return to its normal position preparatory to subsequent energization while undergoing a minimum of bounce.

The solenoid assembly to be described hereinbelow in greater detail, is extremely advantageous for use in the high speed dot matrix printer described in the inventor'copending application Ser. No. 35,405 filed May 7, 1970. The printer described therein is capable of forming characters by selectively impacting one or more of seven vertically aligned slender print wires against an inking ribbon so as to print "dots " upon the surface of the paper document. A plurality of the columns printed are related so as to form any character or symbol, typically within a five by seven dot matrix. Obviously, another size matrix may be employed, if desired. Since printing speed is of the essence in such devices it is therefore very important to provide an apparatus for rapidly impacting the print wires and rapidly returning the print wires to the rest position with a minimum of "bounce" in order that the entire printing assembly may operate at such high speeds. The printing rate in the above mentioned printing apparatus is of the order of 165 characters per second with 60 lines of characters per minute being printed (with each line containing up to 132 characters). To obtain these speeds it is important to provide solenoid assemblies which are capable of moving the slender print wires from the rest position to the impact position and return to the rest position within the time interval of 1 millisecond or less while at the same time providing an impact of sufficient force to print a clearly legible dot upon the paper document or other printing surface.

The present invention is characterized by providing a solenoid assembly of greatly simplified design to facilitate assembly thereof and which incorporates a novel "wagon wheel" spring employed to achieve the characteristics described hereinabove.

The solenoid assembly of the present invention comprises a case for housing the coil and armature. A stem portion threadedly engages the forward end of the housing and is provided with an axially aligned elongated opening for receiving and reciprocally mounting a slender elongated print wire. The rearward end of the print wire is fixedly secured to the solenoid armature at the forward end of the armature. The rearward end of the armature is fixedly secured to a spring member of the "wagon wheel" type at its central portion. The peripheral portions of the spring rest against an annular shaped spacer which abuts a shoulder provided therefor within the solenoid housing. The rearward portion of the armature housing abuts a cap member which threadedly engages and seals the rearward end of the housing. The cap member is adjustable to regulate the amount of stress or tension (i.e., preloading) imposed upon the spring member. A "half spool" member

positioned within the solenoid housing cooperates with the stem member to define an annular shaped hollow interior space for positioning and receiving the solenoid coil. The exposed forward end of the stem portion is threaded so as to threadedly engage an appropriate tapped aperture provided in the solenoid mounting portion of the print head assembly. A tubular wire guide is positioned within the solenoid assembly stem portion and is appropriately lubricated so as to reduce wearing of the reciprocating print wire extending therethrough.

The print head assembly is provided with a plurality of guide means for guiding and directing each of the print wires toward the forward end of the print head housing which is further provided at its forward end with a multi-apertured jeweled member which ultimately aligns the forwardmost ends of the slender print wires along a vertical straight line.

The "wagon wheel" spring means is formed from a flat sheet of prehardened tempered spring steel or any other suitable material exhibiting similar characteristics. The spring has a centrally located hub portion having radially aligned spoke portions extending outwardly therefrom an integrally joined therewith. Each of these spoke portions are provided with arcuate shaped portions integrally joined to their free ends so as to define a substantially circular shaped periphery wherein gaps are provided at discrete intervals about the periphery of the spring, which gaps define the spacing between the outer ends of adjacent arcuate portions. The arcuate shaped portions rest against the spacer member referred to hereinabove while the hub portion of the spring rests against the forward end of the threaded cap member which is adjustably positioned relative to the rearward end of the solenoid housing so as to prestress or preload the spring member and thereby provide the precise amount of loading required to assure appropriate high speed reciprocating operation of the print wires under the control of the solenoid.

The springs maintain the wires of their associated solenoids in the non-printing position when the solenoid coil is deenergized. Upon energization of the solenoid coil, the electromagnetic field tends to urge or pull the armature towards the forward end of the solenoid assembly. This force is counteracted by the spring member which sequentially develops two counteracting spring forces in the following manner.

The initial forward movement of the solenoid armature causes each of the radially aligned spokes to flex, which flexing establishes a counteracting spring force which is substantially linearly related to the movement of the armature. Subsequently thereto, as the armature moves still further in the forward direction, the arcuate portions of the spring provided at the free ends of the spoke portions experience a twisting. The resultant counteracting force developed by the spring thus follows a logarithmic curve whereby the magnitude of the counteracting force increases more rapidly than the otherwise linear force developed by the radial portions of the spring alone. THe initial counteracting force is both small and relatively linear in nature to enable the solenoid armature to be rapidly accelerated. The counteracting force of the spring reaches its maximum magnitude as the slender print wires impact the paper docu-

ment at which time the dots of the character are printed. The deenergization of the solenoid coil places the print wires, which are now in the impact position, under the exclusive control of the counteracting force of the spring which is substantially at its maximum magnitude at this time causing the print wire to rapidly return to the rest position. The flexed spokes, in returning to their normal undeflected position, tend to overshoot their normal rest position. However, the "twisted" arcuate portions tend to counteract the overshooting and thereby more rapidly return the armature and print wire to the rest position with a minimum of overshoot and "bounce".

The threadedly engaging members of the solenoid assembly permit simple rapid assembly of the component parts after which precise adjustments may be made whereupon the adjustable members are then epoxied into position so as to maintain the accurate positioning of the components thereby providing a solenoid assembly which is formed of components whose tolerances may be somewhat imprecise while at the same time are capable of being readily and easily adjusted to produce a solenoid assembly whose operating characteristics lie within highly precise and controlled ranges. The print head housing supports sensing means for precisely registering the lines of "dots" printed.

It is therefore one object of the present invention to provide a novel solenoid assembly for use in high speed dot matrix printers and the like.

Another object of the present invention is to provide a novel solenoid assembly for use in dot matrix printers and the like in which the components are made adjustable so as to facilitate ease of assembly and subsequent precise adjustment thereof.

Another object of the present invention is to provide a spring member of "wagon wheel" design for use in solenoid assemblies.

These as well as other objects of the present invention will become apparent when reading the accompanying description and drawings in which:

FIG. 1 is a sectional view of a solenoid assembly designed in accordance with the principals of the present invention;

FIG. 1*a* is a sectional view of the solenoid case of FIG. 1;

FIG. 1*b* is a sectional view of the solenoid armature of FIG. 1;

FIG. 1*c* is an end view of the cap member of FIG. 1;

FIG. 2 is a plan view of the solenoid spring employed in the assembly of FIG. 1;

FIG. 2*a* is a plot of curves and FIGS. 22 and 2*c* are top end views of portions of the spring of FIG. 2 useful in describing the operation of the spring;

FIG. 3 is a perspective view of a print head assembly employing solenoid assemblies of the type shown in FIG. 1; and

FIG. 4 is a schematic diagram of the solenoid driver circuit.

Referring now to the drawings, the solenoid assembly **10**, shown best in FIG. 1, is comprised of a cylindrical shaped case **11** which is also shown in sectional fashion in FIG. 1*a*. The case is a substantially hollow cylindrical member provided with a recessed shoulder **11***a* spaced inwardly from its left-hand end and a recessed shoulder **11***b* spaced inwardly from its right-hand end. The right-hand or rearward end is threaded at **11***c* for receiving an adjustable threaded closing cap, to be more fully described. An annular groove **11***d* is positioned immediately adjacent the innermost end of tapped portion **11***c*. The forward or left-hand end of casing **11** is further provided with a slot **11***e* through which the leads of the solenoid (to be more fully described) extend so as to couple the solenoid to the peripheral driving circuitry, not shown herein for purposes of simplicity.

The forward (left-hand) end of case **11** receives a stem member **12** having a threaded portion **12***a* for threadedly engaging a tapped mounting hole provided in the print head assembly, which will be more fully described hereinbelow. A lock nut **13** threadedly engages threaded portion **12***a* to firmly secure the solenoid assembly to the print head assembly.

The stem is provided with a circular shaped flange portion **12***b* which is received within the forward end of case **11** whereby the right-hand peripheral edge of flange **12***b* may nominally abut against shoulder **11***a*. The rearward most portion **12***c* of stem **12** has a diameter which is less than both flange **12***b* and threaded portion **12***a* with the extreme right-hand end portion **12***d* being of still further reduced diameter so as to form a shoulder **12***e* positioned between sections **12***c* and **12***d*.

Stem **12** is provided with an axially aligned opening which is comprised of a portion **12***f* of a first diameter and a portion **12***g* of slightly enlarged diameter extending therethrough. The extreme left-hand end portion **12***h* is tapered to form a conical entrance portion to facilitate the insertion of a hollow tubular elongated wire guide **14** which is positioned within opening portion **12***g* so that its right edge abuts against the shoulder **12***j* positioned between portions **12***f* and **12***g* of the axially aligned opening. The wire guide is preferably force-fitted within opening portion **12***g* so as to experience no linear movement relative to stem **12**. The interior of wire guide **14** is preferably coated with a lubricant such as, for example, "Molycote" to reduce wearing of the print wire **15** which is mounted for reciprocating movement therethrough.

A solenoid core member **16** having a tubular shaped portion **16***a* and an outwardly extending flange portion **16***b*, is telescoped upon the right-hand end of stem **12** whereby the left-hand end of hollow cylindrical portion **16***a* abuts against shoulder **12***e* in the manner shown. The hollow cylindrical portion **16***a* is preferably force-fitted upon the right-hand portion **12***d* of stem **12**. The flanges **12***b* and **16***b*, the stem portion **12***c*, the tubular portion **16***a* and the interior surface of case **11** define a hollow interior space which is provided for receiving the solenoid coil **17** whose turns or windings are wound about stem portion **12***c* and tubular portion **16***a* with the axial length of the windings being defined and physically limited by flanges **12***b* and **16***b*. The two end terminals of solenoid coil **17** are wound so as to extend through the slot **11***e* provided in case **11** (see FIG. **1***a*). The coil end terminals **17***a* and **17***b* are shown as extending outwardly through slot **11***e*. A predetermined length of each of the leads **17***a* and **17***b* is mounted within an associated insulating sleeve **17***c* and **17***d*, respectively.

As was described hereinabove, the slender elongated print wire **15** is slidably received by the interior of wire guide **14** and extends still further to the right so as to be

slidably received by the portion 12*f* of the stem axial opening and to protrude therebeyond by a predetermined distance. The right-hand end portion 15*a* of print wire 15 is mounted within an axially aligned opening 18*a* provided within the solenoid armature 18. Armature 18 is a substantially cylindrical shaped member which is further provided with a right-hand portion 18*b* of reduced diameter relative to the main body portion, forming an annular shoulder 18*c*, portion 18*b*, which is further provided with an axially aligned opening 18*d*. A solenoid spring 19 is mounted upon armature 18 so that it s central opening (to be more fully described in connection with FIG. 2) receives reduced diameter portion 18*b* and rests against shoulder 18*c*. A washer 20 is positioned upon spring 19 so that its central opening receives reduced diameter portion 18*b*. A fastening member 21 has a shaft portion (not shown) passing through the openings in washer 20, spring 19 and armature opening 18*d* so as to firmly secure washer 20 and spring 19 to the right-hand end of armature 18.

Spring member 19 has a substantially circular shaped periphery as will be described in detail hereinbelow. A ring shaped spacer member 22 has its left-hand surface bearing against shoulder 11*b* of solenoid case 11 and has its right-hand surface bearing against the periphery of spring 19. The spacer 22, spring 19 and armature 18 are maintained in position within case 11 by means of cap 23 which is provided with a threaded portion 23*a* which threadedly engages tapped portion 11c of case 11. The cap is provided with a projecting portion 23*b* whose left-hand surface bears against the head of fastener 21. An axially aligned opening 23*c* is provided for adjusting the preloading of spring 19 in a manner to be more fully described. A linear groove 23*d* is provided on the left-hand surface of cap 23 to facilitate the insertion of an adjusting tool such as, for example, a screw driver head. By rotating cap 23 within casing 11 the amount of preloading of spring 19 may be easily and accurately controlled.

After assembly of the solenoid, the stem 12 may be accurately positioned relative to casing 11 and maintained in this position by application of a suitable epoxy shown at 24 which, in addition to securing stem 12 to casing 11, serves to provide a moisture seal over slot 11*e*. If desired, a shim in the form of a washer 25 may be positioned between shoulder 11*a* of case 11 and the right-hand peripheral edge of flange 12*b*. As another obvious alternative, the annular periphery of flange 12*b* may be threaded and the interior surface of the extreme left-hand portion of casing 11 may be tapped so as to provide for adjustable threaded engagement between these two members. Deposition of epoxy upon the members in the manner shown at 24 may be provided to rigidly secure stem 12 to case 11 in the desired position.

As was described hereinabove, the amount of preloading imposed upon spring 19 may be controlled by rotation of cap 23 within casing 11. The amount of preloading may be measured by the insertion of a probe through axial opening 23. After precise adjustment of the preloading, epoxy may be deposited at the position 25 shown in FIG. 1*c* in order to rigidly maintain cap 23 in the desired position. From the foregoing it can be seen that the initial assembly of a solenoid can be performed in a simple straightforward fashion since relatively little concern need be given, at the time of initial assembly to final adjustment thereof. For example, the assembly steps may be comprised of mounting core 18 upon stem 12; winding coil 17 about this assembly and inserting the assembly into casing 11. Spacer 22 may then be positioned within casing 11 so as to abut against shoulder 11*b*. The armature assembly comprised of print wire 15, armature 18, spring 19, washer 20 and fastening member 21 may then be inserted into the casing whereby wire guide 15 is passed through the axial opening in stem 12 (which may be fitted with wire guide 14 either before or after insertion of wire 15 therethrough). Finally, cap 23 may be threaded into casing 11 thereby completing the assembly. Final and accurate adjustment of the solenoid assembly may then be performed, at which time epoxy is deposited at the forward and rearward portions of the housing in the manner shown in FIG. 1 to retain the components in their desired alignment.

FIG. 2 is a detailed view of spring 19 which is comprised of a central portion 19*a* having a central opening 19*b* for receiving the reduced diameter portion 18*b* of armature 18. A plurality of radially aligned spoke portions 19*c* are integrally formed with the central portion 19*a* and extend outwardly therefrom. The free ends of spoke portions 19*c* are each provided with arcuate shaped portions 19*d* whose outer edges define a substantially circular shaped periphery. The free ends of adjacent arcuate shaped portions define gaps 19*e* therebetween. As was described hereinabove, the central portion 19*a* engages armature 18 while the marginal portions, arcuate section 19*d* rest upon the right-hand surface of spacer 22 (relative to FIG. 1). It has been found that the provision of gaps 19*e* between the adjacent free ends of arcuate sections 19d significantly increase the operating life of the spring.

In one preferred embodiment of the present invention, the print wires are moved a distance of 0.015 inches from the rest position to the impact position. FIG. 2*a* is a plot which is useful in explaining the operation of spring 19 wherein distance D is plotted against spring force F. The nature of a flexing member, such as, for example, the spoke portions 19*c*, is such that the spring force varies linearly with distance, i.e., $F = kx$, where F is the spring force, x is the flexing or deflection distance, and k is the spring constant. Curve A represents the spring force of a flexing member. Due to the design of the spring 19, however, it has been found that the relationship of force against distance is a logarithmic relationship as represented by curve B of FIG. 2*a*. Although it is not desired to predicate patentability on the theory of operation of the spring, it is believed that the logarithmic relationship is the result of the combined characteristics of the flexing and twisting of the spoke and arcuate shaped portions, respectively, which appear to operate as follows:

Considering FIGS. 2*b* and 2*c*, which are top and end views respectively of one spoke 19*c'* and one arcuate shaped portion 19*d'*, the energization of the solenoid coil causes the armature to move toward the left from the rest position (relative to FIG. 1). The initial movement of armature 18 imparts a force represented by arrow F, as shown in FIG. 2*c*, to be imparted to the spring. The force F initially causes the spokes to flex downwardly as shown by dotted lines 19*c''*. After the

spokes undergo a predetermined amount of flexure it has been found that the arcuate shaped portions, such as, for example, arcuate shaped portion **19***d*, reacts in such a manner that its end portions **19***f* and **19***g* remain stationary while its central portion intermediate the ends experiences a twisting relative thereto, as shown by arrow R, which is the apparent reason for the significant departure from the linear force versus distance relationship to the logarithmic relationship as shown by the respective curves A and B.

When the solenoid coil is deenergized, the magnitude of the spring force is substantially at its maximum value (represented by the value of curve B when the print wires have moved a distance of the order of 0.015 inches) thereby placing the print wire exclusively under control of spring **19**. The large force imposed upon the armature at this time causes a rapid return of the armature toward the rest position. The spoke portions tend to return to their normal undeflected position. The arcuate portions tend to significantly reduce the amount of overshooting which may occur as a result of the movement of the spoke portions toward their normal undeflected state thereby significantly reducing the amount of "bounce" and overshooting which would otherwise occur in springs of conventional design.

In the high speed printer described in the above mentioned copending application Ser. No. 35,405, the print wires are designed to move from the initial rest position through a distance of 0.015 inches to the impact position and return to the rest position within the span of **1** millisecond. Since a typical line may contain 132 characters, any given print wire may experience as many as 660 deflections per line, all of said deflections occuring within the span of less than **1** second. Taken the above high speed operation into consideration with the fact that the printer is intended for use over extremely long periods of time with a minimum of down time, it can be seen that the spring members must be quite rugged while at the same time providing highly uniform operating characteristics for any given individual deflection. This necessitates the provision of a spring member which is dimensionally precise.

FIG. **3** is an exploded perspective view showing a printing head assembly **30** which incorporates solenoids **19** of the type described hereinabove. The assembly **30** is comprised of a body portion **31** having a rear wall **32** provided with a plurality of tapped openings **33** which threadedly engage the threaded portions **12**a of each of he solenoid stems **12**.

Body portion **31** is further provided with first and second pairs of vertically aligned guide slots **34** and **35** for receiving positioning members **36** and **37** which are respectively positioned within the guide slots to align the slender print wires therethrough. A plurality of wire guides **38** extend through appropriate openings provided in positioning members **36** and **37** to guide the print wires therethrough. The interiors of the hollow elongated tubular members **38** are preferably lubricated to reduce wear.

The forward end of housing **31** is provided with an opening **39** and a pair of guide slots **43***a* and **43***b* for receiving and positioning a jeweled member **44** which, in turn, is provided with a plurality of vertically aligned openings for receiving each of the print wires.

Housing **31** is further provided with a pair of outwardly extending flanges **44***a* and **44***b* each having tapped openings **45** for threadedly engaging fastening members to secure the print head housing to mounting plates **46***a* and **46***b* which form a part of the printer and serve to move the print head along a horizontal line to successively print a plurality of vertical columns of dots, with the total number of dots per column being selectively controlled in accordance with the particular character or symbol to be printed.

The rear end of housing **31** further supports a registration device **60** shown in FIG. **3**a and includes a pair of supporting members **61,61** for securing assembly **60** to housing **32**. A plate **63** is secured to members **61,61** and supports a lamp **64** and a photo-head **65** suspended from the underside of plate **63**. A stationary mylar strip **66** having a plurality of narrow transparent slits **67** is mounted in spaced parallel fashion relative to the printer platen (not shown). As the print head assembly moves in the direction of arrow A during a printing operation, light passes through a transparent slit and impinges on the photo-head **65**. The light is carried by a fiber optic bundle **68** to a photocell **69** to activate the photocell only when passing a transparent slit. The photocell generates a pulse which enables the solenoids to be energized only at the positions of the narrow transparent slits thus assuring accuracy in the locations of the dots printed regardless of the speed of movement (i.e., at a constant or a non-constant speed) of the print head assembly.

FIG. **4** is a schematic diagram showing the driver circuitry employed for selectively driving solenoids of the type shown in FIG. **1**. Since the driving circuits for each solenoid are all identical in both design and operation, only one of the circuits will be described herein for purposes of simplicity.

As shown in FIG. **4**, the driving circuit **50** is provided with an input terminal **51** normally coupled to one of the seven outputs of a character generator of the type described in the aforementioned application Ser. No. 35,405. **'When the output of the character generator coupled to input terminal** 51 **is low, input terminal** 51 **is held at ground potential and no current flows through resistor** R4. **When the output of the character generator goes high, then current flows through resistor** R4. **If diode** D1 **is back-biased, the current flows into the base of transistor** Q3. **This current, in turn, causes current to flow through resistor** R3 **and transistor** Q3, **thereby establishing a voltage across Zener diode** ZD1. **This voltage causes transistors** Q2 **and** Q1 **to act as emitter followers, thereby developing a voltage drop across resistor** R1. **Resistor** R2 **limits the power dissipation in transistor** Q2. **The voltage drop across resistor** R1 **causes a collector current of the order of** 2.5 amps to flow through transistor Q1. When the stage first turns ON, the inductance of the solenoid prohibits the current from flowing through transistor Q1 and at this point transistor Q1 is saturated. When the current flowing through the solenoid reaches approximately 2.5 amps, transistor Q1 goes into an active region and limits the current at this value.

When transistor Q1 shuts OFF, the current flowing through the solenoid passes through diode D2 and causes capacitor C1 to charge. The value of capacitor C1 is chosen to act as a parallel resonant circuit with

the inductance in the solenoid. Diode D2 allows only one-quarter wave of this characteristic frequency to be developed thereacross.

After the capacitors of each charging circuit (one charging circuit of the type **50** shown in FIG. **4** is provided in each solenoid) have charged to approximately 60 volts due to the discharge of the printer solenoids, resistor R4 serves to bleed off this charge so that the capacitors will be at a 30 volt bias at the time of the next discharge. The value of the resistor is chosen so that a time constant of about 275 microseconds results.

Each diode D1 of each of the driver circuits of the type **50** shown in FIG. **4** have their cathodes tied together and connected to the collector of transistor Q4 in the manner shown. When the printer is normally running, a voltage is developed across relay R1 to close its relay contact C1 to prohibit current from flowing through diode D3 and into the base of transistor Q4, thereby insuring the transistor Q4 is shut off. In this condition, each diode D1 of each driver circuit cannot shunt current away from the solenoid drivers. When the printer is shut off, however, the power supply which energizes relay R1 will drop before the power supply employed to operate the solenoid driver circuits **50**. When this happens, relay R1 opens, thereby allowing the current to flow through resistor R6 and diode D3 into the base of transistor Q4, thereby saturating Q4. This causes all the bases of the solenoid drivers to be tied to ground through their diodes D1, thus preventing any of the solenoids from firing on shut off. As shown in FIG. **4**, each solenoid and solenoid driver circuit is protected against overload current by a fuse F1.

Although not shown for purposes of simplicity, it should be understood that a cover member is positioned upon housing **31** so as to keep the interior of housing member **31** free from contamination.

It can be seen from the foregoing description that the present invention describes a solenoid assembly especially adapted for use in printers of the dot matrix type in which high speed of the print wires comparable with present day printers are obtained due to the nature of the design of the solenoid assembly and of the springs employed therein which are further designed to provide a unique operation not heretofore obtained in the performance of such components.

Although there has been described a preferred embodiment of this novel invention, many variations and modifications will now be apparent to those skilled in the art. Therefore, this invention is to be limited, not by the specific disclosure herein, but only by the appending claims.

What is claimed is:

1. A solenoid assembly comprising:
a hollow case;
a stem having an axial aligned opening of small diameter extending the length of said stem;
said stem having a flange intermediate its ends secured to the forward end of said case and having its rearward portion extending into the interior of said case;
an annular shaped coil positioned within said case and surrounding a portion of said stem;
a threaded cap threadedly engaging the rearward end of said case;
said cap having a projection extending into said case;
an armature positioned within said case and along the axis of said case, at least the forward portion of said armature extending into the rearward portion of said coil;
a slender print wire positioned within the axial opening of said stem and having its forward end extending beyond the forward end of said stem and its rearward end secured to the forward end of said armature;
circular shaped spring means having its central portion secured to the rearward portion of said armature;
the projection of said cap abutting against the rearward portion of said armature and being adjustable to adjust the pre-loading of said spring;
said case having an annular shoulder engaging the periphery of said spring;
said spring being formed of a resilient metallic sheet and having a circular central portion;
a plurality of radially aligned portions each being integrally joined to and extending outwardly from said central portion;
the outer ends of each radially aligned portion having a pair of arcuate shaped ears extending from opposite sides of said radially aligned portions; **16**
the free end of each ear being a spaced distance from the free end of an adjacent ear whereby all of said ears define a circular shaped periphery whose marginal portion abuts against said annular shoulder.

2. The solenoid assembly of claim **1** wherein said spring is formed from a sheet of spring steel.

3. The solenoid assembly of claim **1** wherein said spring is adapted to exert a rearwardly directed force on said armature to normally hold said print wire in the non-impact position when said solenoid coil is deenergized, said coil being adapted to overcome the rearward directed force of said spring when energized to rapidly move said print wire toward the impact position, and thereby flex said spring to cause said print wire to return rapidly to the non-impact position when said coil is deenergized while reducing bounce and overshooting of said armature.

4. A print head assembly comprising:
a housing having a rear wall and a front wall joined by a pair of side walls;
a plurality of solenoid assemblies each comprising:
a hollow case;
a stem having an axial aligned opening of small diameter extending the length of said stem;
said stem having a flange intermediate its ends secured to the forward end of said case and having its rearward portion extending into the interior of said case;
an annular shaped coil positioned within said case and surrounding a portion of said stem;
a threaded cap threadedly engaging the rearward end of said case;
said cap having a projection extending into said case;
an armature positioned within said case and along the axis of said case, at least the forward portion of said armature extending into the rearward portion of said coil;
a slender print wire positioned within the axial opening of said stem and having its forward end extending beyond the forward end of said stem and its

rearward end secured to the forward end of said armature;

circular shaped spring means having its central portion secured to the rearward portion of said armature;

the projection of said cap abutting against the rearward portion of said armature and being adjustable to adjust the preloading of said spring;

said case having an annular shoulder engaging the periphery of said spring;

said spring being formed of a resilient metallic sheet and having a circular central portion;

a plurality of radially aligned portions each being integrally joined to and extending outwardly from said central portion;

the outer ends of each radially aligned portion having a pair of arcuate shaped ears extending from opposite sides of said radially aligned portions;

the free end of each ear being a spaced distance from the free end of an adjacent ear whereby all of said ears define a circular shaped periphery whose marginal portion abuts against said annular shoulder;

said rear wall having a plurality of openings for mounting said solenoids to said rear wall;

said print wires extending through said rear wall and between said side walls toward said front wall;

said front wall having openings each adapted to receive the free end of an associated one of said print wires;

said front wall openings being arranged to be along a straight line;

said rear wall openings being aligned with their axes generally converging toward said front wall.

5. The assembly of claim further comprising a stationary elongated strip having a plurality of spaced transparent openings along said strip;

said assembly being movable along a line parallel to said strip;

a light source mounted upon said housing and being positioned on one side of said strip;

light sensitive means being mounted upon said housing and being positioned along the opposite side of said strip so as to sense light emitted from said light source when said light source passes a transparent opening for generating a pulse to control the energization of said solenoids only upon passing one of said transparent openings.

6. The assembly of claim **5** wherein said light sensitive means comprises a photo head mounted immediately adjacent said opposite side of said strip and secured to said housing;

a photocell secured to said housing;

a fiber optic bundle coupled between said photo head and said photocell to pass light from said light source impinging upon said photo head to said photo cell.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,690,431 Dated September 12, 1972

Inventor(s) Robert Howard

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 25, the word "an" should be -- and--;
line 63, the word "THe" should be --The--;

Column 3, line 53, "22" should be --2b--;

Column 7, line 36, the word "occuring" should be--occurring--;
line 36, the word "Taken" should be "Taking--;

Column 8, line 43, delete the apostrophe "'" before "When";

Column 10, line 26, delete "16";

Column 12, line 5, insert "4" after "claim" and before --further--

Signed and sealed this 18th day of February 1975.

(SEAL)
Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents
and Trademarks

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