United States Patent

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[54] **HIGH SPEED ACTUATOR ASSEMBLY**
7 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** 234/115
[51] **Int. Cl.** G06k 1/05
[50] **Field of Search** 234/115

[56] **References Cited**
UNITED STATES PATENTS
3,127,100 3/1964 Schmidt 234/115
3,412,932 11/1968 Masterson et al. 234/115

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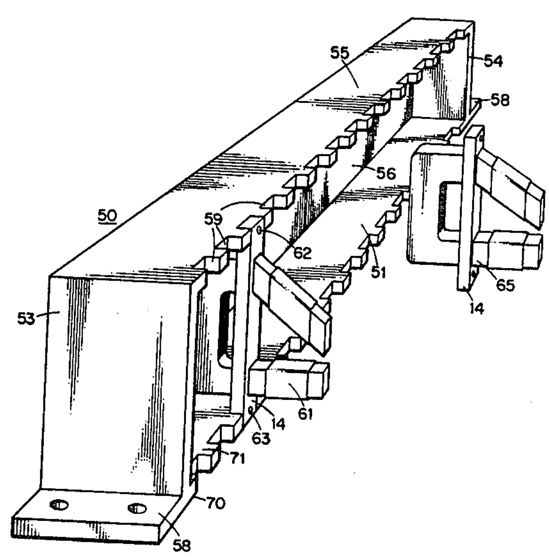
ABSTRACT: A plurality of magnetic interposers comprising an actuator assembly utilized in a multihead high-speed punch. Each magnetic interposer operates a single punch knife and comprises a permanent magnet, a pair of magnetic pole face elements joined together by a solid magnetic shunt and having selectively energizable windings thereon, and a magnetic flexure spring having one end fixed to translate along a prescribed axis with respect to said pole face elements. The free end of the spring is held in a flexed no-punch position against the pole faces by permanent magnet force, released by a selectively applied electromagnetic force to spring into a punch position, and then returned to the no-punch position by a selectively applied electromagnetic force of reverse magnitude. In the punch position the spring is stiffened by a preform whereby a vertical punching force may be transmitted axially therethrough to a punch knife. The magnetic elements of a plurality of identical interposers are confined in a housing of nonmagnetic material which holds the elements in spaced fixed alignment with respect to a corresponding plurality of flexures and punch knives while shielding them to minimize magnetic crosstalk or other interference between the magnetic circuits of the respective interposers. A dummy interposer is mounted in each end of the housing to provide a more uniform magnetic field across the entire actuator assembly.



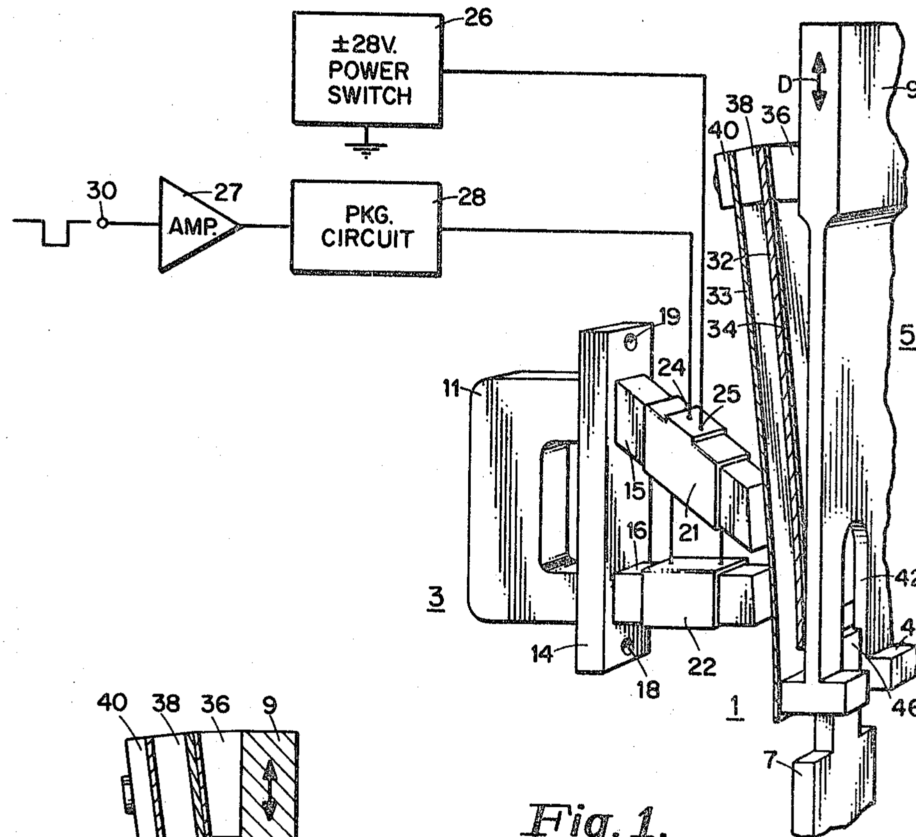


Fig. 1.

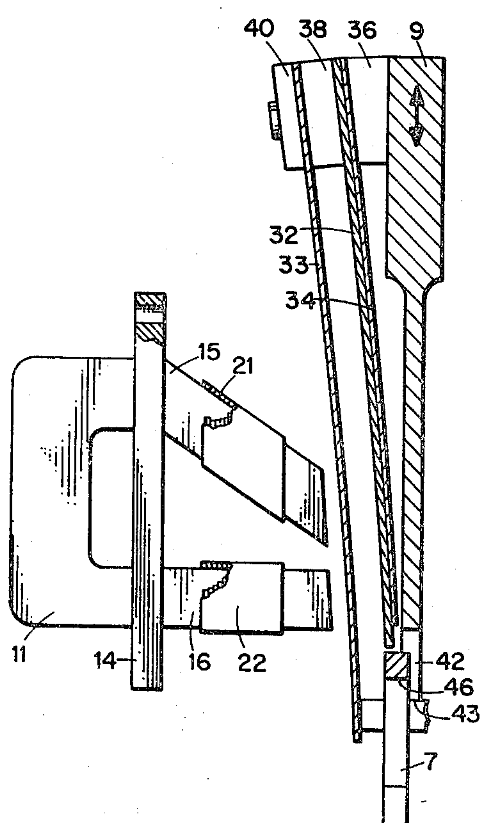


Fig. 2.

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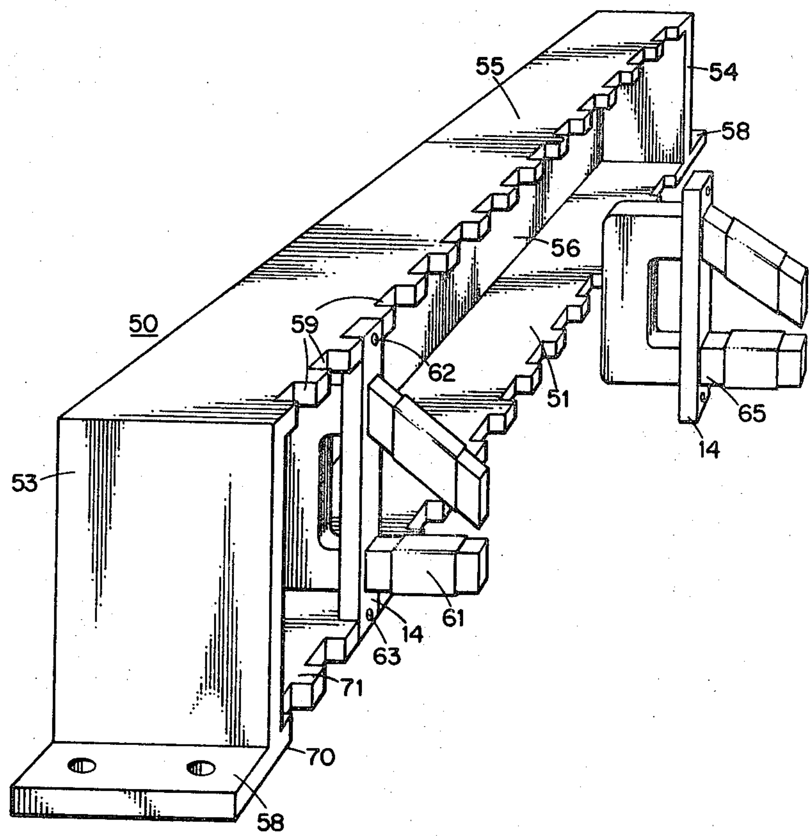

Fig. 3.

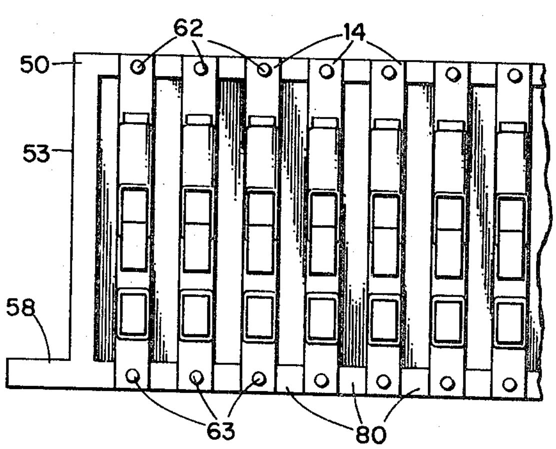

Fig. 4.

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HIGH SPEED ACTUATOR ASSEMBLY

BACKGROUND OF THE INVENTION

The present invention relates to an improved assembly of mechanical actuators capable of reliable operation for extended periods at high speed. In particular, the actuator assembly of the present invention includes a plurality of improved actuators having magnetic interposers and being disposed in a novel housing whereby interference between the magnetic circuits of the interposers is greatly reduced.

For purposes of illustration the invention will be described in conjunction with a multihead card punch unit wherein the invention has special application. However, it will be understood that the novel assembly has utility in a number of other widely varied applications.

A universal requirement in the operation of a multihead high-speed punch unit is the rapid and synchronous operation of all punches which are simultaneously selected. Conventionally, this is accomplished by applying reciprocating linear motion from a common motive source to a plurality of actuators each adapted to transmit the motion to a corresponding punch knife. Each actuator includes an interposer which is selectively positioned in alignment with the punch knife to transmit driving force thereto when punching is desired. One key to reliable operation then resides in the ability to shift the interposers rapidly and synchronously from a power transmitting to an inactive position or vice versa. A second key to satisfactory operation resides in the ability to reliably shift the interposers which have been selected.

Heretofore available high-speed punch equipments have been relatively complex and expensive; generally including numerous pivots and wearing mechanisms which must be properly lubricated. The interposer was usually conducted to a moving armature whereby the total mass to be moved was relatively large and the speed of operation therefore limited. Partially due to such complexity, the prior equipments were subject to breakdowns under sustained periods of operation. Since card punch equipments are usually part of a larger data processing system, such breakdowns result in great hourly costs.

U.S. Pat. No. 3,411,709 to Earl E. Masterson describes a multihead punch assembly wherein a more recently developed type of actuator including a magnetically operated flat leaf flexure is used. In the Masterson actuator wear is minimized by the absence of pivot joints and other points requiring lubrication. Consequently, the actuator is easy to maintain in proper operating condition for extended periods. In the actuator design a flat leaf flexure of magnetic material is normally held in a flexed nonoperative position by the force of a permanent magnet. An electromagnetic force which opposes the permanent magnet force is selectively applied to free the flexure whereby it springs into a punch position so that a punching force may be applied axially therethrough to a punch knife. Upon completion of the punching operation, the electromagnetic force is terminated and the leaf flexure is returned to the flexed position by the permanent magnet. The multihead punch is comprised of two columns of 12 punches oriented adjacent to each other to span two columns of a data processing card. The columns of punches and driving means therefore are arranged between two opposed actuator assemblies each comprising 12 actuators. The 12 actuators of an assembly are arranged in side-by-side relationship in a unitary housing which holds the actuators in alignment with respect to the punch heads and driving means.

The Masterson actuator assembly is a significant improvement over the prior art in that it is extremely simple and reliable. However, the Masterson actuator and assembly have certain inherent characteristics which limit their use in an ultra high-speed punch operation. For example, in the construction of the Masterson actuator assembly the pole face elements of the individual actuators are mounted upon a pair of plates of magnetic material which extend the full length of the assembly housing. An air gap between the plates operates as a shunt in the magnetic circuit of each individual actuator. In view of the high permeativity of the air gap, the shunt is inoperative until the magnetic flux in the pole faces reaches a high value. Consequently, when current is applied to the windings on the pole faces, a certain amount of electromagnetic flux circulates through the permanent magnet of the actuator. Repeated application of electromagnetic flux to the permanent magnet will eventually cause a change in the retentivity of the magnet and a corresponding change in the control of its interposer. Since the magnetic circuits of the actuators of the assembly share common mounting plates of magnetic material, a certain amount of crosstalk or magnetic interference also occurs between adjacent actuators. This in turn causes changes in the remanence levels of the magnetic circuits of the actuators and results in variations in the current levels required to shift an interposer of any predetermined actuator.

SUMMARY OF THE INVENTION

Accordingly, it is a primary object of the present invention to provide a novel actuator assembly which overcomes the foregoing disadvantages and permits reliable high-speed operation.

It is another object of the present invention to provide a mechanical actuator assembly which responds more rapidly and reliably to selectively applied control signals.

It is a further object of the invention to provide a simple and economical card punch unit utilizing magnetic flexure means wherein wear is minimized by the absence of pivots and other points requiring lubrication.

It is yet a further object of the present invention to provide an actuator assembly utilizing a housing of nonmagnetic material which prevents crosstalk or other magnetic interference between actuators within the assembly.

It is another object of the invention to provide an actuator assembly comprising magnetic actuators having solid shunts joining adjacent pole faces to achieve a more reliable and efficient magnetic operation.

The foregoing objects are accomplished by a novel apparatus designed in accordance with the present invention utilizing actuators having reverse current driven magnetic interposers. Each actuator includes a permanent magnet, a pair of pole face elements joined together by a solid shunt of magnetic material and having selectively energizable windings thereon, and a magnetic flexure which is moved between a punch position and a no-punch position under the positive control of selectively applied electromagnetic forces. Thus, a free end of the flexure is normally held in a flexed no-punch position adjacent the magnet pole faces by permanent magnet force, released to spring into a punch position by selectively applied electromagnetic force, and then returned to the no-punch position by a selectively applied opposing electromagnetic force. While in the punch position the spring is stiffened by a preform so that a punching force may be transmitted axially through the spring to a punch knife. The actuator assembly of the present invention comprises a plurality of identical interposers having their magnetic elements confined in a housing which holds the elements in spaced, fixed alignment with respect to a corresponding plurality of flexures and punch heads. The magnetic circuit of each actuator includes a solid shunt of magnetic material joining the pole face elements upon which the windings are retained to attain more efficient operation. The respective actuators are confined in a novel housing of nonmagnetic material wherein the magnetic portions of the actuators are shielded by teeth of nonmagnetic material and crosstalk between magnetic circuits of the individual actuators is minimized. A dummy actuator is mounted in each end of the housing to provide a more uniform magnetic field across the entire assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

Further objects of the invention together with features and advantages thereof will become apparent from the following detailed description when read in conjunction with the accompanying drawings in which:

FIG. 1 is a perspective view of a single actuator, having a magnetic interposer of the type used in the novel assembly of the present invention;

FIG. 2 is a partial sectional view showing details of the interposer and the magnetic circuits of an actuator utilized in a high-speed punch;

FIG. 3 is a perspective view of a housing adapted to confine a plurality of magnetic elements to form an actuator assembly in accordance with the present invention; and

FIG. 4 is a fragmentary front elevation view of an actuator assembly of the type shown in FIG. 3.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings the invention will be explained with reference to a multihead punch unit wherein the medium which is to be perforated, e.g., a card, moves in conventional manner below the lower end of the punch knife which has been omitted in the drawing for simplicity. A multiple punch unit with which the present invention could be utilized is described in U.S. Pat. No. 3,411,709 to Masterson, mentioned above. Such a punch unit includes 24 individual punches disposed in columns of 12 punches each which are adapted to be simultaneously actuated. The actuator assemblies, each comprising 12 actuators, are located on either side of the punch columns in generally opposing relationship. It should be understood that while the invention is described in conjunction with a multihead punching unit it could be used in any other application wherein a plurality of high-speed actuators are necessary.

An actuator 1 of the type used in the present invention is shown as generally comprising a magnetic unit 3 and an interposer 5 arranged to operate a punch knife 7 to permit the selective application of punching force to the knife from a reciprocating column 9. The magnetic unit 3 includes a permanent magnet 11 of a suitable high retentivity material such as Alnico V and a pole face unit 12 including a shunt 14, upper pole face bar 15, and lower pole face bar 16. The upper bar, lower bar and shunt are all formed of a suitable low retentivity magnetic material such as Cast Armaco. The pole face unit may be cast as a single structure or the upper and lower bars may be bonded to the shunt 14 in any suitable fashion to provide a unitary structure. As shown, the shunt 14 is provided with openings 18, 19 therethrough by which the magnetic unit is supported in the assembly in a manner described hereinafter. The permanent magnet is fixed against the shunt, in alignment with the upper and lower bars and may be held in that position by its own force. However, an adhesive binding tape, now shown, is preferably used to retain the permanent magnet against slippage. An upper winding 21 is located on bar 15 and a lower winding 22 is provided on bar 16. As shown, these windings are electrically connected in series to terminals 24, 25 on the upper side of bar 15 and are wound in a direction to create, respectively, aiding magnetic flux in the shunt and pole face elements. The windings may be prewound and slipped over the insulated ends of bars 15, 16 thereafter being covered by a protective coating of a suitable insulator, such as a plastic material.

Windings 21, 22 are adapted to be energized by a driving circuit which includes power switch 26, a switching amplifier 27 and a peaking circuit 28, in response to punch logic control signals applied to terminal 30 by a conventional punch control selection unit, not shown.

The interposer 5 is shown fixed to and carried with column 9 which reciprocates vertically as indicated by the arrow D under the influence of a conventional eccentric drive shaft and cam arrangement, not shown. The interposer includes an elongate flexure 32 of magnetic spring material mounted between a no-punch preform 33 and a punch preform 34. Flexure 32 and preform 34 are fixed adjacent each other and separated from column 9 by a spacer 36. Spacer 38 separates flexure 32 from no-punch preform 33 by a predetermined air gap. Suitable fastening means 40 are provided to hold the magnetic spring, preforms and spacers in fixed alignment against the punch column. Preform 33 rests adjacent the faces of bars 15,16 and serves as a guide for flexure 32 in the no-punch position; while flexure 32 rests adjacent preform 34 in the punch position. Preform 34 serves to stiffen the flexure whereby it serves as a column to transmit punching forces axially applied thereto. The preforms are fabricated of any suitable nonmagnetic material and are of predetermined thickness sufficient to provide the desired stiffness.

By referring to FIGS. 1 and 2 a better understanding of the movement of the interposer during a punching cycle can be gained. Thus, in the no-punch position flexure 32 is held adjacent preform 33 under the influence of the permanent magnetic field. In this position flexure 32 is out of contact with the stationary punch knife 7 which travels freely along slot 42 in column 9 as the latter reciprocates Consequently no force is applied to the punch knife when the flexure is in the no-punch position.

When a punch signal is received by the driving circuit of the actuator, an electromagnetic force is applied in opposition to the permanent magnet force, sufficient to release the flexure 32 and permit it to spring into contact with preform 34 adjacent column 9. In the latter position flexure 32 is vertically aligned with the top of punch knife 7 shown on FIG. 2 in its uppermost position. With flexure 32 aligned in the punch position an axial force is applied through the stiffened flexure to punch knife 7 as column 9 moves downward. This punch force is sufficient to drive the punch knife down through a data processing card or document. As the punch column travels upward stripper 43 of column 9 engages step 46 of the knife and withdraws it to an upper position wherein it clears the freshly punched hole in the card. During this upward translation a reverse current is applied by the driver circuit to create an electromagnetic force of opposite magnitude in the actuator magnetic circuit sufficient to withdraw flexure 32 into its no-punch position adjacent preform 33. Once flexure 32 is in firm contact with preform 33, the electromagnetic force is terminated and the flexure is retained in position only by the force of the permanent magnet.

The corresponding state of the magnetic circuit of the actuator should be apparent from the sectional view of FIG. 2. Thus when windings 21, 22 are unenergized the flux in the circuit is due only to the permanent magnet 11. The flux from the permanent magnet traverses two paths; the first path including the shunt 14, and the second path including pole face element 15, the air gap between element 15 and flexure 32, the flexure itself, the air gap between the flexure and pole face element 16, and the pole face element itself. It should be apparent that the air gaps are of higher permeativity than the solid shunt of magnetic materials whereby the majority of permanent magnet flux will normally traverse the shunt. In actuality about 20 percent of the permanent magnet flux appears across the air gaps between bars 15, 16 and flexure 32. Accordingly, any change in the retentivity of the permanent magnet does not change the critical operating level of the magnetic circuit significantly.

When the windings 21, 22 are energized to create electromagnetic force aiding the permanent magnet force, the entire electromagnetic flux appears across the air gaps. Under this condition the shunt 14 acts as a low reluctance path whereby the permanent magnet is not subject to the electromagnetic flux. Likewise when windings 21, 22 are energized with a reverse current and an opposing electromagnetic flux is created, the shunt 14 acts as a low reluctance path for the electromagnetic flux as well as for any permanent magnet flux which does not pass across the air gaps between poles 15, 16 and the flexures. In short the provision of a magnetic shunt of low retentivity material results in a higher sensitivity in the magnetic circuit whereby a faster more reliable mode of operation is achieved.

Referring now to FIG. 3 a housing of suitable design for use in an actuator assembly of the present invention is shown. A first actuator is mounted in the housing, while a second actuator is shown in exploded relationship thereto. The housing **50** is constructed of a suitable nonmagnetic material such as aluminum, formed in the shape of a rectangular box having a bottom **51**, sides **53, 54**, a top **55**, a backwall **56** and a front opening **57**. The bottom **51** is provided on either end with flanges **58** having openings therethrough by which the housing may be mounted to a frame of a multihead punch unit, not shown. The front edges of the bottom **51** and top **55** are provided with slots **59** therein to accommodate the shunts **14** of magnetic actuators of the type shown in FIG. 1. Actuator **61** is shown confined in its home position in the housing **50** by screws or pins **62, 63** while actuator **65** is shown in exploded relationship to the housing. In the complete assembly shown in FIG. 3 a total of 14 actuators would be mounted in the housing. The 12 center actuators are designed to operate punch knives corresponding thereto. The actuators of either end of the assembly are dummy units used to provide a uniform magnetic field across the assembly. Thus it should be apparent that an actuator mounted in the center of the assembly would be exposed to stray magnetic fields from the several actuators mounted on either side. However, an actuator mounted at or near the end of the assembly would be exposed to a lesser degree of stray magnetic fields since it is proximate to a lesser number of actuators. In order to equalize such variations in stray magnetic fields the dummy actuators are mounted at either end of the assembly and are designed to have a higher level of magnetic strength than the working actuators. Consequently, each working actuator is exposed to a uniform level of stray magnetic field. It should be understood that an assembly designed in accordance with the present invention could include any suitable plurality of actuators necessary for a particular application.

The housing **50** may be manufactured by a casting operation with the slots **59** and other reference surfaces being machine finished by conventional methods. Surface **70** of the bottom **51** is manufactured to a finished tolerance as is the inner lip **71**. The bottom of the shunt **14** of each actuator is also finished to a close tolerance whereby the actuators are aligned in spaced fixed relationship to each other and to their corresponding flexures and punch knives when mounted in the housing **50**. The permanent magnets are held to the shunt **14** by their own force and rest against the lip **71** whereby the ends of the magnet are located in alignment with the ends of bars **15, 16** to provide uniform magnetic circuits for all the actuators.

Referring now to FIG. 4 a fragmentary front elevational view of an actuator assembly is shown. Five actuators are shown spaced apart in the housing **50**, with their respective magnetic circuits being separated by air gaps and shielded by teeth **80** of nonmagnetic material. It should be apparent that the actuator assembly of the present invention comprises a rigid composite group of actuators having the operative portions thereof presented to the interposers in perfect alignment. Furthermore, magnetic interference or crosstalk between the magnetic circuits of the adjacent actuators is minimized, if not eliminated. This feature of the invention, along with the provisions of solid shunts **14** joining the pole face bars, results in highly accurate and selective magnetic circuits which are critically responsive to switching signals applied thereto and highly stable over long periods of operation.

It should also be apparent that the provision of separate magnetic circuits for each actuator, comprising a permanent magnet, solid shunt **14** and pole face elements **15, 16**, results in highly accurate, selective, and easily serviced magnetic circuits which are precisely responsive to switching signals applied thereto and highly stable over long periods of operation. One of the important factors in providing magnetic stability is the opportunity to independently magnetize each permanent magnet to a predetermined flux level. This is accomplished by magnetizing the permanent magnet to a very high level and then deenergizing it to an accurately established, desired flux level.

We claim:

1. An actuator assembly including:
   - a housing and a plurality of magnetic interposers confined therein, adapted to operate a corresponding plurality of working elements;
   - each said interposer having a separate array of magnetic circuit elements including means for selectively generating magnetic flux in said magnetic circuit and a solid shunt of magnetic material connected between a pair of spaced pole face elements;
   - said housing being formed of nonmagnetic material and including a reference surface thereon;
   - means for receiving and confining the ends of each said shunt on said housing to locate the magnetic circuit elements of said respective interposers in spaced fixed relationship to said reference surface and said corresponding plurality of working elements; and
   - shielding means for isolating the magnetic elements of each interposer from the magnetic circuit elements of the other interposers in said assembly to prevent magnetic interference therebetween.
2. An actuator assembly including:
   - a housing and a plurality of magnetic interposers confined therein, adapted to operate a corresponding plurality of working elements;
   - each said interposer having a separate array of magnetic elements including means for selectively generating magnetic flux in said magnetic circuit and a solid shunt of magnetic material connected between a pair of spaced pole face elements;
   - said housing being formed of nonmagnetic material and including a reference surface thereon;
   - said housing further including a pair of parallel opposed sides, each of said sides having a plurality of slots formed in an edge thereof adapted to receive the ends of the magnetic shunts of said respective interposers;
   - means for fastening said shunts in said slots for confining the magnetic circuit elements of said respective interposers in spaced fixed relationship to said reference surface and said corresponding plurality of working elements; and
   - shielding means for isolating the magnetic elements of each interposer from the magnetic circuit elements of the other interposers in said assembly to prevent magnetic interference therebetween.
3. An actuator assembly as described in claim 2 wherein the array of magnetic circuit elements of each said interposer further includes a separate permanent magnet attached to said magnetic shunt.
4. An actuator as described in claim 2 wherein the material between the slots in said housing sides comprises shielding teeth adapted to minimize magnetic crosstalk between the magnetic circuits of said interposers.
5. An actuator assembly for a high-speed punch having a plurality of working heads, comprising:
   - a shielded housing of nonmagnetic material and
   - a plurality of magnetic interposers confined therein, each of said interposers being adapted to selectively operate a predetermined one of said working heads;
   - each said interposer having a separate array of magnetic circuit elements including a permanent magnet section, magnetic shunt means connected across the poles of said permanent magnet, a pair of pole face elements connected, respectively, at the ends of said shunt means to define a working air gap therebetween and electrical winding means mounted on said pole face elements;
   - each of said interposers further including armature means adapted to be operated between a nonactive position and an active position by a predetermined level of magnetic flux in said air gap and circuit means for selectively applying electrical power to said winding means;

said housing being formed in the shape of an open sided rectangular box defined by opposed top and bottom sides each having a front edge adjacent said open side, and opposed ends, said sides and ends being joined to a backwall; and

said bottom having a reference surface formed thereon, the front edges of said top and bottom sides being formed with a plurality of pairs of spaced slots therein, adapted to receive, respectively, the magnetic shunt means of a corresponding plurality of interposers, and means for fastening said shunt means in said slots whereby the interposers are aligned in spaced fixed relationship to said reference surface and said working heads.

6. An actuator assembly as described in claim **5** wherein each of said shunt means comprises a solid bar of magnetic material.

7. An actuator assembly as described in claim **5** further including shielding means for isolating the magnetic elements of each interposer from the magnetic circuit elements of the other interposers in said assembly to prevent magnetic interference therebetween.