Nov. 18, 1969 D. F. WILKES 3,479,624

MAGNETICALLY OPERATED SWITCHING APPARATUS

Filed March 29, 1968 2 Sheets-Sheet 1

FIG. 1

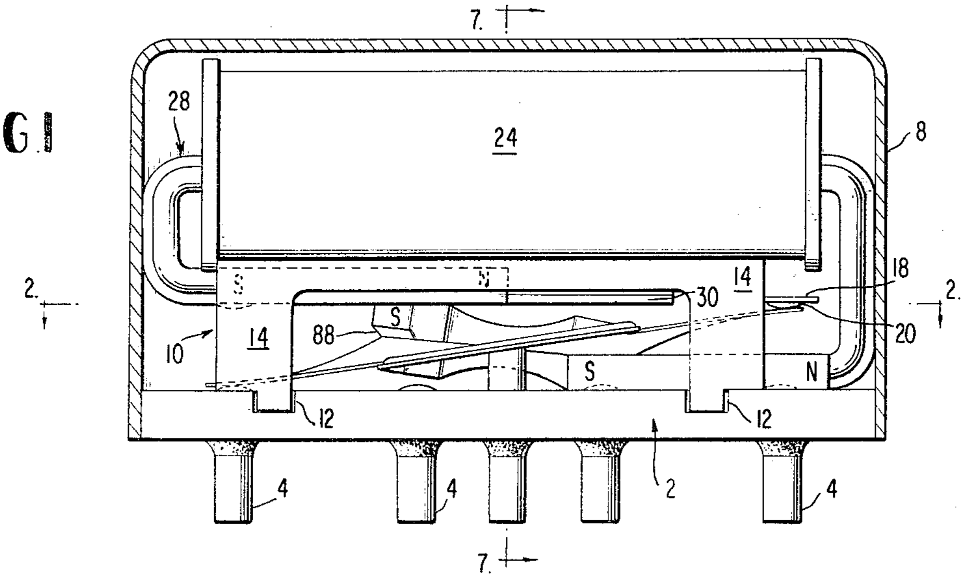


FIG. 2

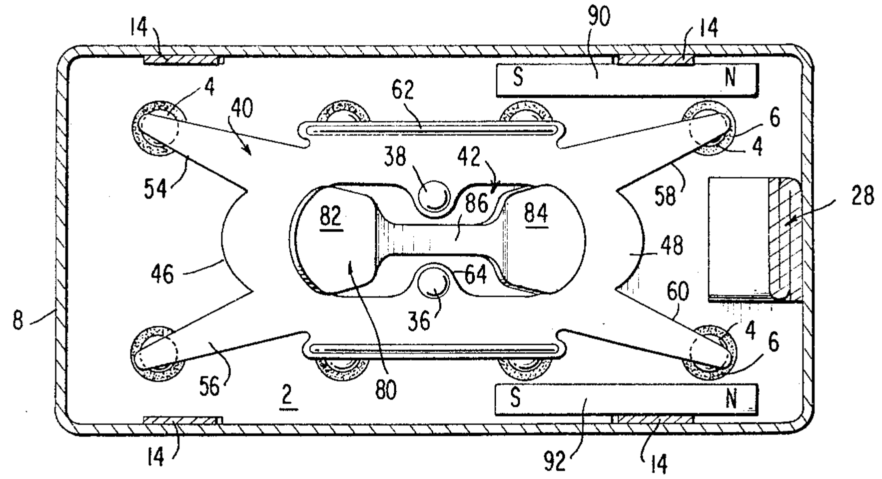


FIG. 3

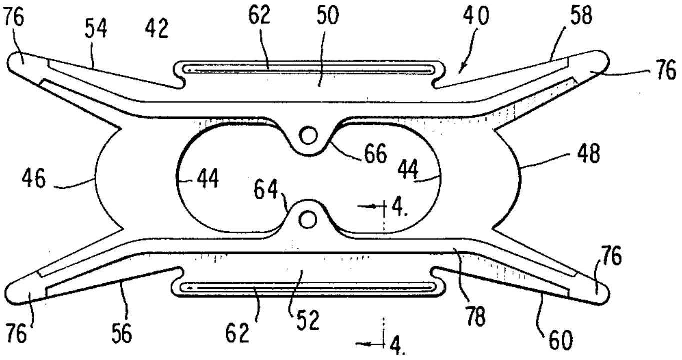
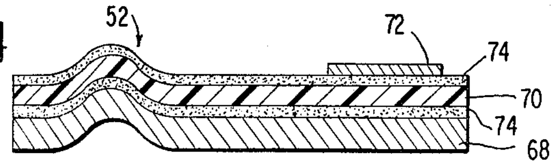


FIG. 4



INVENTOR
DONALD F. WILKES
BY Burns, Doane, Benedict, Swecker & Mathis
ATTORNEYS

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MAGNETICALLY OPERATED SWITCHING APPARATUS

Filed March 29, 1968 2 Sheets-Sheet 2

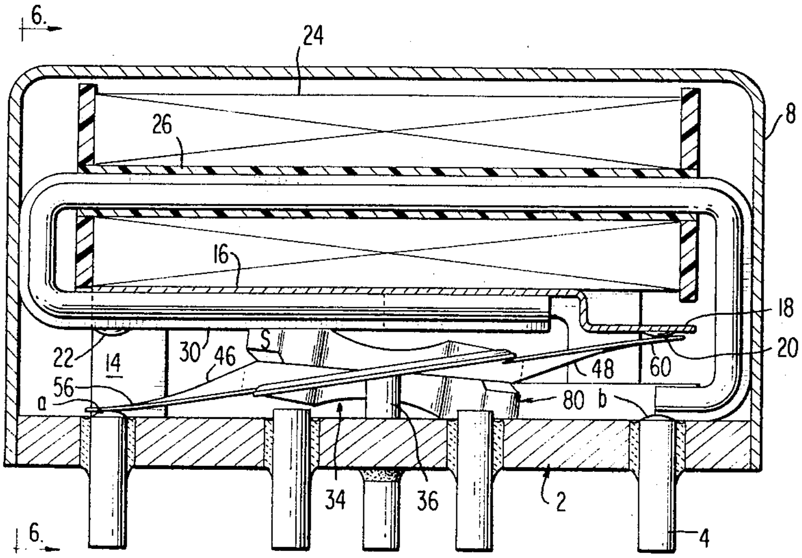

FIG.5

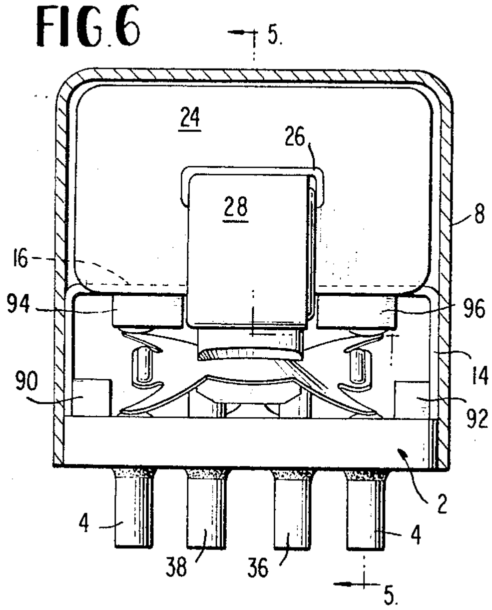

FIG.6

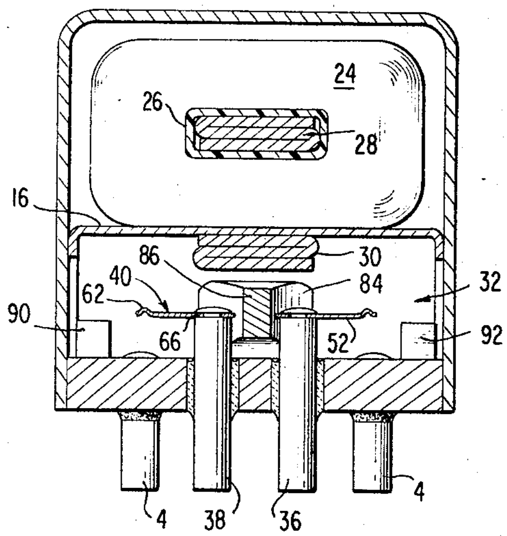

FIG.7

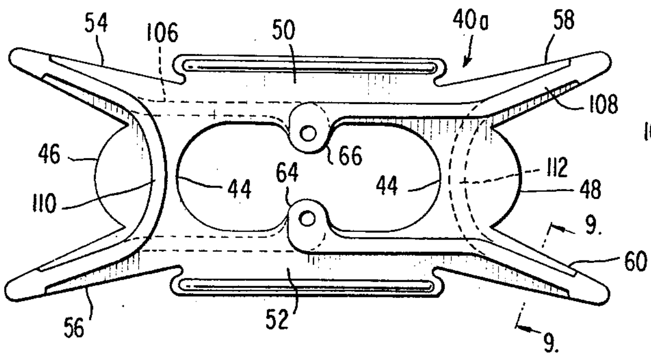

FIG.8

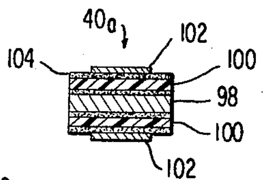

FIG.9

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3,479,624
MAGNETICALLY OPERATED SWITCHING APPARATUS

Donald F. Wilkes, Albuquerque, N. Mex., assignor to Rolamite Technology, Incorporated, San Francisco, Calif., a corporation of California

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Int. Cl. H01h 5/02
U.S. Cl. 335—188 11 Claims

ABSTRACT OF THE DISCLOSURE

A relay having elongated pole elements between which is positioned a tiltable armature connected to a resilient snapper element having a pair of bi-stable segments. Tilting movements of the armature in response to coil energization cause the snapper segments to snap back and forth between their stable positions to make and break electrical contact with stationary contact elements.

CROSS REFERENCES TO RELATED APPLICATIONS

Two patent applications of Donald F. Wilkes entitled respectively "Snap Action Apparatus" and "Electrical Contact Making and Breaking Apparatus" are being filed concurrently herewith. These applications disclose related subject matter, and the disclosures thereof are incorporated herein by reference.

BACKGROUND OF THE INVENTION

This invention relates to magnetically operable switching apparatus in which an armature is caused to move in response to magnetic forces and in which movements of the armature serve to actuate bi-stable snap-acting elements that carry out electrical switching functions. The invention is particularly suitable for use in miniature relay constructions.

In the design of relays and other types of magnetically operable switching apparatus, much attention has been given heretofore to the problem of maximizing magnetic flux utilization. This problem becomes particularly important in connection with small devices in which coil size must be restricted because of space limitations and/or because of limited heat dissipating capabilities. However, the proposed solutions have been only partially successful, and in most of the prior art constructions the positional relationships between the movable armatures and the magnetic pole pieces have been such that the flux paths have been unnecessarily inefficient.

Difficulties also have been experienced in obtaining efficient electrical contact making and breaking functions in these magnetically operable devices. In a typical relay construction for example, a movable contact element is held against a back contact by a spring of some sort and is moved against the action of the spring by the armature to draw it away from the back contact and bring it into engagement with a front contact upon energization of the relay coil. However, a critical analysis of the force-space relationships inherent in such devices makes it evident that they cannot be operated to produce sharp definitive contact breaking functions unless the coils are capable of quickly generating very large magnetic forces.

Moreover, the prior art proposals are in general difficult to apply in connection with the design of small devices which must be manufactured on a mass production basis. In such applications, dimensional tolerances become exceedingly critical and irregularities in the materials from which the parts are fashioned are troublesome.

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SUMMARY OF THE INVENTION

The magnetically operable switching apparatus of this invention overcomes or avoids the difficulties and problems outlined above. A key feature of the new apparatus is an improved armature-movable contact assembly which, in a preferred embodiment, includes an elongated armature permanently magnetized along the direction of its length and a snapper element of thin resilient material having a central opening disposed in surrounding relationship to the armture. In the assembled positions of these parts, the snapper element is elastically stressed in patterns which cause the end portions thereof protruding beyond the ends of the armature to cone out of the plane of the armature. The elastically coned end portions of the snapper are bi-stable. Each of them may assume coned configurations extending either above or below the plane of the armature.

In the assembled apparatus, the coned snapper segments at opposite ends of the armature are caused to extend away from the plane of the armature in opposite directions. Opposing stationary reaction surfaces are located in the paths of movement of the free outer end portions of the snapper segments and serve to limit the extent of movement of these portions.

Some or all of the reaction surfaces may be electrically conductive, and the snapper element is provided with electrically conductive surface portions for cooperating with the electrically conductive reaction surfaces. In addition to providing movable contacts, the snapper element may also bear whatever circuit elements may be desired.

The armature-movable contact assembly is disposed between a pair of elongated magnetic pole pieces and mounted so as to permit tilting movements of the armature about an axis located approximately midway between the ends of the armature and midway between the pole pieces. The extent of tilting movement permitted however is limited by the presence of the opposed pole pieces. In one extreme position of the armature, its "north" end will contact one of the pole pieces while its "south" end contacts the other of the pole pieces. In the other extreme position of the armature, an opposite relationship between its ends and the respective pole pieces will prevail.

Movement of the armature between its extreme positions under the influence of magnetic forces applied through the pole pieces will function first to increase the bearing forces between the outer end portions of the snapper segments and the reaction surfaces, and then to suddenly snap the snapper segments into the oppositely directed stable positions thereof.

This construction has many practical advantages. For example, flux utilization is optimized by the novel arrangement of the armature with respect to the pole pieces, and the snap actions achieved in the snapper end segments in response to armature movements assure effective contact making and breaking operations.

An equally important attribute of the construction is that it may be manufactured reliably on a mass production basis. The snapper element is formed from thin sheet material which is highly uniform in its structural properties, and the outlines of the element may be established with precision through the use of photochemical processing techniques analogous to those employed in chemical milling operations and in the production of printed circuit components. Additionally, there are very few critical dimensional relationships in the entire construction so that it generally is not necessary that close tolerances be maintained in the fabrication of the components or in assembling such components.

BRIEF DESCRIPTION OF THE DRAWINGS

A better understanding of these and other features and advantages of the invention will be gained from a consideration of the following detailed description of certain embodiments illustrated in the accompanying drawings, in which

FIGURE 1 is an elevational view, with a casing component illustrated in cross section, of a small relay embodying the principles of the invention;

FIGURE 2 is a horizontal cross-sectional view taken along line **2—2** in FIGURE 1;

FIGURE 3 is a plan view of a resilient snapper element suitable for use in the relay of FIGURES 1 and 2;

FIGURE 4 is an enlarged, transverse cross-sectional view taken along the line **4—4** in FIGURE 3;

FIGURE 5 is a longitudinal cross-sectional view taken along the line **5—5** of FIGURE 6;

FIGURE 6 is an end elevational view of the left end of the relay, with a portion of the casing being shown in cross section;

FIGURE 7 is a transverse vertical cross-sectional view generally along the line **7—7** in FIGURE 1;

FIGURE 8 is a plan view, similar to FIGURE 3, but illustrating an alternative snapper configuration suitable for use in relays of the type illustrated in FIGURE 1; and

FIGURE 9 is an enlarged vertical cross-sectional view taken along the line **9—9** in FIGURE 8.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The relay chosen for illustration in the drawings is a small device sometimes characterized in the trade as a "half crystal can" relay. It includes a base member **2** having contact pins **4** mounted therein and electrically insulated therefrom by suitable ceramic material **6**. For reasons which will become clear hereinafter, the material from which the base **2** itself is formed, should be one which will give the base a high capacity for transmitting magnetic flux. A cover **8** of suitable non-magnetic material fits tightly over the periphery of the base **2** to provide an enclosure for the coil and switching components. If desired, hermetic seals may be provided between the cover **8** and the base **2** so as to protect the interiorly located components against the deteriorating influences of environmental gases.

A bracket structure **10** of suitable non-magnetic material is attached to the upper surface of the base **2** as indicated at **12**. This bracket structure **10** includes four vertically extending leg portions **14** and a horizontal platform **16** (FIGURE 7), one end portion **18** of which is disposed at a level beneath the main body of the platform as indicated in FIGURE 5. The portion **18** is provided with laterally spaced apart reaction surfaces such as those shown at **20**, and additional reaction surfaces **22** at the opposite end of the device are supported at the same level by means to be described below. In some forms of the invention, these reaction surfaces **20** and **22** will be electrically conductive and will serve as stationary contacts. Each of the downwardly facing reaction surfaces is directly above one of the contact pins **4**.

An electrical coil **24** wound on a generally rectangular core form **26** is supported by the main body portion of the platform **16** at an elevation above the base **2** of the relay. Extending through the core form **26** is an elongated element **28** of a material such as soft iron, which will serve as a good conductor of magnetic flux.

The element **28** is formed from an elongated, somewhat thin, sheet. The desired thickness is achieved by folding the sheet back and forth upon itself as indicated in FIGURE 7. This folded construction gives the element **28** ample flux-carrying capacity, but the element as a whole is relatively easy to bend.

At the left end of FIGURE 5, the element is shown as being bent downwardly as it emerges from the end of the coil **24**. Then, it is bent again at the level of the platform **16** and caused to extend longitudinally along the lower face of the platform **16**. Spot welds, or the like, may be employed to secure the end portion of the element **28** to the platform **16**.

The element **28** also is bent downwardly as it emerges from the right end of the coil **24** in FIGURE 5. This downwardly extending portion of the element **28** is connected at its lower end to the base **2** of the relay by spot welding or other appropriate techniques.

The combination of the element **28** with the base **2** establishes an extraordinarily efficient flux-conducting system. The longitudinally extending portion **30** of the element **28** on the underside of the bracket platform **16** constitutes one pole base or element, while the base **2** constitutes an opposed pole base or element disposed in generally parallel relation to the element **30**. The bent configurations imparted to the element **28** make it possible for this element to join the two pole pieces together with only one joint. This joint is the one which exists between the base **2** and the lower right end portion of the element **20** in FIGURE 5. Even this joint is one which can be formed so as to minimize flux leakage because of the compliant nature of the surfaces of the element **28**.

Moreover, it will be evident that, in constructions where ample space is available, the element **28** may be extended longitudinally so that the end portion from the right end of the coil will be disposed beneath and parallel to the portion **30**. In such constructions there need be no joint at all.

The pole element **30**, the base **2** and the downwardly facing reaction surfaces **20** and **22** define a shallow elongated switching chamber **32**. Disposed in this switching chamber is a novel armature-movable contact assembly **34** carried by transversely spaced-apart central posts **36** and **38** which may be attached to the base **2** in the same fashion as the contact pins **4**.

FIGURE 3 illustrates in isolation, a thin, lightweight, resilient snapper element **40** which forms an important part of the novel armature-movable contact assembly. This snapper element **40** is provided with an elongated central opening **42** having concave end edge portions **44** which define the inner ends of protruding end segments **46** and **48**. The end segments **46** and **48** are joined together by longitudinally extending side strips **50** and **52**.

Each of the end segments **46** and **48** has an external edge outline such as to provide the segment with a pair of protruding contact fingers. The finger portions of the segment **46** are designated **54** and **56**, while the finger portions of the end segment **48** are designated **58** and **60**. These finger portions constitute integral parts of the respective end segments **46** and **48**, and in the illustrated arrangement, each pair of fingers functions as a mechanical unit.

The side strips **50** and **52** are provided with longitudinally extending stiffener ribs **62** at their outer margins. These stiffening ribs **62** are formed by conventional stamping techniques which serve to permanently deform the material of the snapper element **40** in the zones of the ribs.

The side strips **50** and **52** also include mounting tabs **64** and **66** extending inwardly into the central opening **42** at a mid portion of the element. These tabs **64** and **66** are, in the assembled relay, affixed to the upper ends of the mounting posts **36** and **38** in the manner indicated in FIGURE 7.

As illustrated in FIGURE 4, the snapper element **40** is a laminate, made up of a bottom layer **68** of spring-metal sheet material, an insulating layer **70** of plastic material such as a polyester sheet, and a partial top surface layer **72** of electrically conductive material such as copper. The several layers **68, 70** and **72** are adhered together through sheet adhesive layers **74**. It will be understood of course that the thickness of the laminate is greatly exaggerated in FIGURE 4. In one embodiment, the overall thickness of the laminate is only 0.004 inch, and in applying the invention, it will rarely be found necessary to use snapper elements thicker than a few hundredths of an inch.

The outlines of the electrically conductive layer **72** may form patterns of considerable intricacy. Photochemical processing techniques of the type used in the manufacture of printed circuits are available for economically tailoring the final shape of the partial layer **72** in any desired manner. The particular shape illustrated in FIGURE 3 is one which provides the upper face of the snapper **40** with electrical contact surfaces **76** at the free outer ends of the several contact fingers **54, 56, 58** and **60**. The contact surfaces **76** on the fingers **56** and **60** are connected together by a portion **78** of the electrically conductive layer **72**, and this portion **78** is, in turn, extended into the mounting tab **64** of the snapper **40** so that an electrical outlet connection may be made through the mounting post **36**.

An armature **80** is mounted within the central opening **42** in the snapper element **40**. The armature **80** preferably is permanently magnetized along the direction of its length. In the drawings, the left end portion of the armature has been designated a south magnetic pole and the right end portion has been designated a north magnetic pole for illustrative purposes.

This armature **80** includes enlarged end portions **82** and **84** connected together by an elongated center portion **86**. Each of the end portions **82** and **84** is curved convexly in the areas which are to cooperate with the concavely curved end portions **44** of the edge of the central opening **42** of the snapper element **40**. As shown in FIGURES 1 and 5, notches or grooves **88** are provided in the outer edges of the armature end portions **82** and **84** for receiving the curved edges **44** of the snapper.

Certain of the dimensional relationships between the armature **80** and the edges of the central opening **42** in the snapper element **40** are important. The radius of curvature of the base of each of the notches **88** is less than the radius of curvature of the curved edge **44** associated therewith. Additionally, the length of the armature, as measured from the base of one groove **88** to the base of the other groove **88** is greater than the distance between the curved edge portions **44** if measured when the snapper **40** is in a flat condition. Hence, when the snapper **40** and the armature **80** are in their assembled relation to each other, the snapper is distorted elastically. The curvatures of the edges **44** of the central opening **42** of the snapper are made to conform to the curvatures of the bases of the grooves **88** in the end portions of the armature **80**, and the snapper end segments **46** and **48** cone elastically out of the plane of the central opening **42** as best shown in FIGURES 1 and 5.

The armature **80** has an overall shape such that it contacts the snapper **40** only in the zones of the curved end portions **44** of the central opening **42**. The side strips **50** and **52** do not contact the armature at all and they are permitted to assume configurations which will serve to distribute the stresses in the snapper **40**.

Each of the end segments **46** and **48** is bi-stable. It may assume one stable position in which its top face is convex and in which it extends downwardly at an angle from the plane of the central opening **42**, or it may assume another stable position in which its top face is concave and in which it extends upwardly at an angle from the plane of the central opening **42**.

In the assembled device, the two coned end segments **46** and **48** of the snapper are arranged to operate out of phase with each other in the sense that when the snapper segment **46** is coned downwardly, the snapper segment **48** will be coned upwardly and vice-versa. With this arrangement, the mid portions of the side strips **50** and **52**, where the mounting tabs **64** and **66** are located, have little tendency to move as the positions of the end segments **46** and **48** are reversed. This makes it possible to use a rigid connection between the mounting posts **36** and **38** and the mounting tabs **64** and **66**. The distortions which result are of minimal magnitude and are easily accommodated by the flexible nature of the material of the snapper **40**. Moreover, the flexible pivot provided by the connection of the snapper mounting tabs to the upper ends of the mounting posts **36** and **38** tends to reduce the importance of locating the upper ends of the mounting posts exactly at the middle of the switching chamber. Minor positional deviations can be accommodated by the material of the snapper **40** without detracting from the performance characteristics of the device.

The upper and lower faces of the end portions **82** and **84** of the armature extend at angles to the horizontal, and, as shown in FIGURES 1 and 5, these faces may be brought into abutting relationship with the magnetic pole elements **30** and **2**. This provides a closed magnetic path for the device in either extreme position of the armature **80**. Flux will pass, for example, from the left end of the coil **24** through the element **28** to the pole portion thereof **30**, through the armature **80** to the base **2**, and then back again to the right end of the coil through the right end portion of the element **28**.

If, as in the illustrated embodiment, it is desirable that the armature have a "normal" position so as to provide the relay with normally closed or normally open contacts, the interior of the switching may be provided with permanent magnets for holding the armature in one of its extreme positions. In the drawings, two such magnets **90** and **92** are shown extending along the right end portion of the base **2** with their south magnetic poles disposed in the vicinity of the north magnetic pole of the armature **80**. Similarly, permanent magnets **94** and **96** are carried by the bracket platform **16** on opposite sides of the pole element **30** and are disposed so that their north magnetic poles will be in the vicinity of the south magnetic pole of the armature.

The upper magnets **94** and **96** preferably have substantial widths as indicated in FIGURE 6, so that the upper stationary reaction surfaces **22** may be formed on or carried by the lower faces of the magnets. These reaction surfaces **22** are disposed directly above the pins **4** at the left end of the relay.

With the magnets **90, 92, 94** and **96** in place, the armature **80** will be held in the extreme position illustrated in FIGURES 1 and 5 until the coil **24** is energized to override the permanent magnets. Energization of the coil **24** serves to make the pole element **30** a south magnetic pole and to make the base **2** a north magnetic pole. The magnetic forces so generated operate first to repel the end portions **82** and **84** of the armature and tilt the armature about a transverse axis corresponding approximately to a line between the upper ends of the mounting posts **36** and **38**. As the motion of the armature continues, the repulsion forces become less important and attractive forces between the pole piece **30** and the armature end portion **84**, and between the base **2** and the armature end portion **82** dominate the operation of the device and serve to bring the armature into a position of rest in which the upper face of the armature end portion **84** abuts against the pole piece **30** and the lower face of the armature end portion **82** abuts against the base **2**.

Of course, in many applications, it will not be necessary or desirable that the armature be biased toward a "normal" position. In these instances the permanent magnets **90, 92, 94** and **96** will be removed and the reaction surfaces **22** will be formed on or carried by appropriately located elements depending from the main level of the bracket platform **16**.

With the magnets **90, 92, 94** and **96** removed, the permanently magnetized armature **80** will be free to latch magnetically in either of its extreme positions when the coil **24** is deenergized. In one of its latched positions (FIGURE 5), a closed flux path will extend from the south magnetic pole to the armature, through the pole piece **30** and the core members **28**, and then through the base **2** to the north magnetic pole of the armature. In the other latched position, the south magnetic pole of the armature will engage the base **2**, and the closed flux path will extend in a reverse direction through the member **28**.

Provisions will, of course, be made for energizing the coil **24** selectively in either direction. Upon energization of the coil **24** in the proper direction, the flux path through the core member **28** may be reversed from the direction established by the latching action, and the armature **80** may be shifted to its other extreme position.

During the tilting movement of the armature **80**, the inner ends of the snapper blades **46** and **48** will be moved relative to the outer ends thereof. In explaining this action, it will be helpful to refer to particular ones of the stationary reaction surfaces defining the switching chamber in which the armature-snapper assembly is located. In FIGURE 5, a first reaction surface, located at the top of the leftmost contact pin **4** in this view, has been designated *a*; and a second reaction surface, located at the top of the rightmost contact pin **4** in this view, has been designated *b*. A third reaction surface **22** is directly above and faces the first reaction surface *a*. A fourth reaction surface **20** is directly above and faces the second reaction surface *b*. The finger portion **56** of the snapper blade **46** extends into the space between the first and third reaction surfaces, and the finger portion **60** of the snapper blade **48** extends into the space between the second and fourth reaction surfaces. Ordinarily, a similar set of four reaction surfaces would be provided for cooperation with the finger portions **54** and **58** of the blades so as to provide a balanced force pattern, but it will not be necessary here to complicate the description by specific references to these additional features.

The initial movement of the armature **80** in a counterclockwise direction in FIGURE 5 serves to increase the bearing pressures between the finger **56** and the reaction surface *a* and between the finger **60** and the reaction surface **20**. This results in a transverse flattening or buckling of the outer end portions of the fingers **56** and **60**, and, as the motion of the armature is continued, the flattening progresses inwardly toward the armature. When the flattening effect has progressed to the inner boundaries of the snapper blades **46** and **48**, the blades will snap over to their reversely coned configurations and the fingers **56** and **60** will move quickly into engagement with the third and second reaction surfaces **22** and *b* respectively.

The contact fingers **54, 56, 58** and **60** cone with their corresponding end segments **46** and **48**, and they will, by reason of this coning effect, be able to transmit substantial forces. The spatial relationships within the switching chamber are such that this ability is utilized effectively. In order that substantial contact pressures may be generated when the armature **80** is in either of its extreme positions, the space between opposing upper and lower reaction surfaces is restricted to such a degree that the several contact fingers are not able to assume their fully relaxed coned configurations over their entire lengths. The outer end portion of each contact finger will bear against an adjacent reaction surface with substantial pressure and will tend to flatten somewhat.

Additional loading as between the contacts is achieved during initial movements of the armature. In fact, the contact pressure continues to increase until snapover of the snapper segments **46** and **48** occurs. This is most desirable in that good contact is maintained during contact break sequences, and little or no arcing or contact heating will occur. Moreover, the increased loading of the contacts during initial portions of the armature movements will cause the surface portion **76** of the contact fingers to scrape against the stationary contacts provided by the reaction surfaces, and the contacts will be kept clean.

Another attribute of the illustrated construction which deserves special comment is that the motions of the armature **80** are greatly amplified in the motions of the tips of the contact fingers **54, 56, 58, 60**. The armature itself tilts through a relatively small angle, but the bi-stable blades **46** and **48** snap through large angles. As a result, large air gaps between electrical contacts may be established, so as to permit the handling of high potentials, without requiring large air gaps in the magnetic circuits. In this latter connection, it will be observed that in the illustrated embodiment, the distances between the pole piece **30** and the nearest end of the armature **80**, and between the base **2** and the nearest end of the armature **80**, will always be very short indeed. Since the force exerted by a magnetic field varies inversely with the square of the distance, the exceedingly compact armature-pole piece arrangement provided by the invention makes it possible to minimize the size of the coil **24** without adversely affecting the performance characteristics of the device as a whole.

Even greater motion amplifications may be achieved if desired by changing the proportions of the armature **80** and the snapper element **40**. The angles at which the blades **46** and **48** cone away from the plane of the armature are established by the curvatures of the armature end portions and the end edge portions **44** of the snapper element, and these angles may be the same in assemblies of different lengths. Hence, by increasing the length of the armature, one may reduce the angle of tilt of this element without causing corresponding reductions in the angles through which the blades **46** and **48** snap in response to tilting movements of the actuator.

The relative masses of the armature **80** and the snapper element **40** in the illustrated embodiment also are of interest. As explained above, the snapper element is very thin and light. However, the armature **80** may be much thicker and heavier in order that it may have completely adequate flux carrying capacity. Increases in the inertia of the armature are not ordinarily detrimental because of the small amount of armature movement required and because of the flexible coupling between the armature and the snapper element. In this latter connection, it will be observed that the inertia of the armature has little to do with the operation of the snapper blades as they move into engagement with the stationary contacts. When a blade has been snapped over its neutral position, the blade movements required to complete the snap action, take place substantially without regard to further movements of the armature. Thus, bouncing of the armature as it comes to rest in its extreme position will not ordinarily be accompanied by undesired contact bounce effects. Moreover, the extremely low masses of the snapper blades themselves minimize the inertial energy which must be dissipated in contact making sequences so that, in practice, the contact bounce problem is effectively eliminated.

Although the armature **80** chosen for illustration in the drawings is comparatively massive and although such constructions are preferred in some practical applications of the invention, it should be understood that this feature is not essential. Armatures of low mass may be used if desired. Reductions in armature mass might be indicated, for example, in applications where maximum speed of armature movement is required.

FIGURE 8 shows another form of snapper element which has been designated **40*a***. It is of the same configuration as the snapper element **40** shown in FIGURE 3, and corresponding reference numerals have been applied in the two views to all parts except the electrical circuit components.

As shown in FIGURE 9, the snapper **40*a*** is formed from a laminate suitable for the production of circuit components on both faces of the snapper. This laminate includes a spring-metal central layer **98**, a pair of insulating layers **100**, and a pair of electrical conductive layers **102** on the outer surfaces of the component. The several layers are adhered together, as shown through adhesives **104**.

With such a laminate, the circuits on the two faces of the snapper **40***a* may be independent or they may cooperate with each other. For purposes of illustration, FIGURE 9 shows a circuit portion **106** on the bottom face of the snapper which may be made to cooperate with a circuit portion **108** on the top face of the snapper by providing suitable means for connecting these circuit portions together at the location of mounting tab **66**. Other circuit portions **110** and **112** located respectively on the top and bottom surfaces of the snapper are entirely independent of each other.

Still other variations and modifications will readily suggest themselves to persons skilled in the art. It is intended, therefore, that the foregoing detailed description of the illustrated embodiments be considered as exemplary only and that the scope of the invention be ascertained from the following claims.

What is claimed is:

1. In magnetically operable switching apparatus, an improved armature-movable contact assembly comprising:

a magnetic armature having a longitudinal axis and a transverse axis and being tiltable about said transverse axis; and

a thin, lightweight, resilient snapper element having front and back faces at least one of which bears an electrical contact, said element being provided with a central opening therein disposed generally in surrounding relation to said armature;

said snapper element being connected to opposite longitudinal ends of said armature at opposite ends of said central opening and being elastically stressed adjacent said opposite ends of said opening so as to cause each of the protruding end portions of said resilient element to seek a three-dimensional shape corresponding generally to the surface of a segment of a cone with said protruding end portions respectively extending away from said opening at angles on opposite sides of the plane of said opening.

2. In magnetically operable switching apparatus, the improved armature-movable contact assembly according to claim **1**, wherein said armature is permanently magnetized in a direction such that said opposite longitudinal ends thereof are of opposite magnetic polarity.

3. In magnetically operable switching apparatus, the improved armature-movable contact assembly according to claim **2**, wherein the mass of said armature is substantially greater than the mass of said snapper element.

4. In magnetically operable switching apparatus, the improved armature-movable contact assembly according to claim **1** in combination with first and second longitudinally elongated, spaced-apart, generally parallel, stationary pole elements disposed on opposite sides of said transverse axis in position to be contacted respectively by opposite end portions of said armature when said armature is tilted about said transverse axis.

5. A relay comprising:

an electrical coil;

means defining one side of an elongated, shallow switching chamber and including

a first longitudinally extending magnetic pole element operatively connected to one end of said coil, and

first and second stationary, longitudinally spaced-apart, reaction surfaces at least one of which is electrically conductive;

means defining the opposite side of said switching chamber and including

a second longitudinally extending magnetic pole element facing said first magnetic pole element and being operatively connected to the opposite end of said coil,

a third reaction surface facing said first reaction surface, and

a fourth reaction surface facing said second reaction surface;

a permanently magnetized, longitudinally elongated armature in said switching chamber having end portions of opposite polarity and being tiltable about a transverse axis located intermediate said end portions between two positions in each of which its respective end portions are adjacent opposite ones of said pole elements; and

a thin springy snapper element connected to the end portions of said armature and including

elastically stressed, bi-stable end portions coning angularly away from the ends of the armature in opposite directions and extending respectively into the space between said first and said third reaction surfaces and the space between said second and said fourth reaction surfaces,

longitudinally extending side portions spaced from said armature and connecting said snapper end portions together, and

electrical contact means carried by at least one of said snapper end portions at a location to engage an electrically conductive one of said reaction surfaces.

6. A relay according to claim **5**, wherein a pair of transversely spaced apart stationary mounting posts extend into said switching chamber and intersect said transverse axis, wherein said snapper side portions are connected to said mounting posts at the location of said transverse axis, and wherein said snapper element and said armature are connected together only at the end portions of said armature.

7. A relay according to claim **5** wherein the mass of said armature is substantially greater than the mass of said snapper element.

8. A relay according to claim **5** wherein said end portions of said armature include angularly extending front and back faces adapted to be brought into parallelism with the adjacent surfaces of said pole elements upon completion of a tilting movement of said armature between said two positions.

9. A relay according to claim **5** additionally comprising permanent magnet means in said switching chamber for holding said armature in one of the two positions thereof when said coil is unenergized.

10. A relay according to claim **5**, wherein said means defining said one side of said switching chamber is in the form of a base plate having contact pins extending therethrough and being insulated therefrom, and wherein said base plate constitutes said first magnetic pole element and the upper ends of said pins constitute said first and second reaction surfaces.

11. A relay according to claim **10** comprising means for mounting said coil above said switching chamber.

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BERNARD A. GILHEANY, Primary Examiner

H. BROOME, Assistant Examiner