May 26, 1970 P. E. UGON 3,514,728

FREE VANE MAGNETIC CIRCUIT

Filed Nov. 3, 1967 3 Sheets-Sheet 1

Fig. 1.

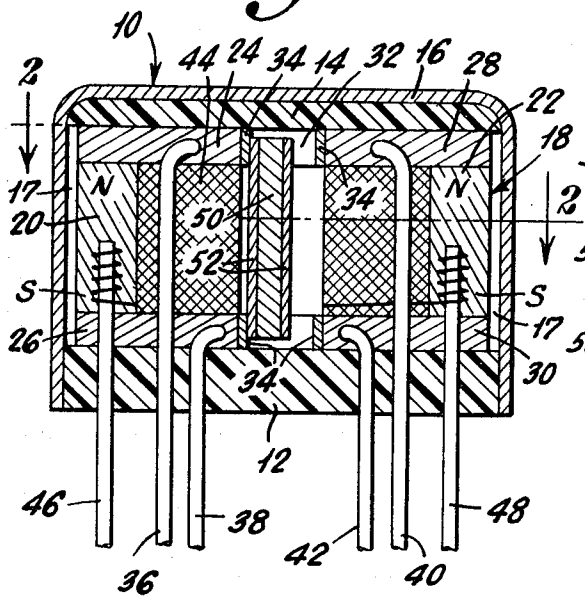


Fig. 3.

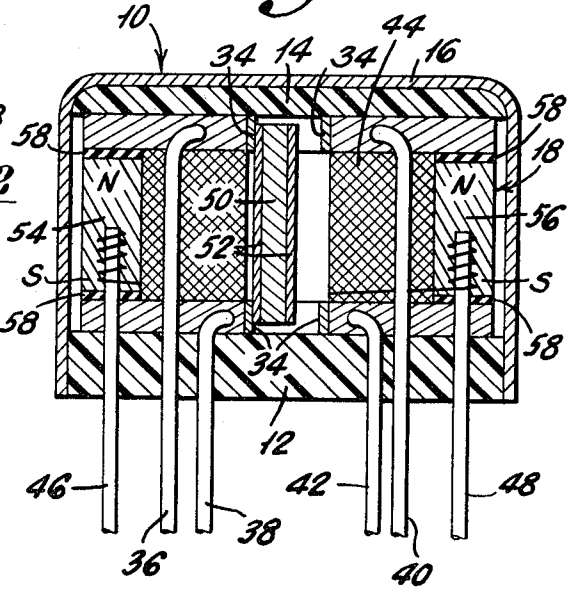
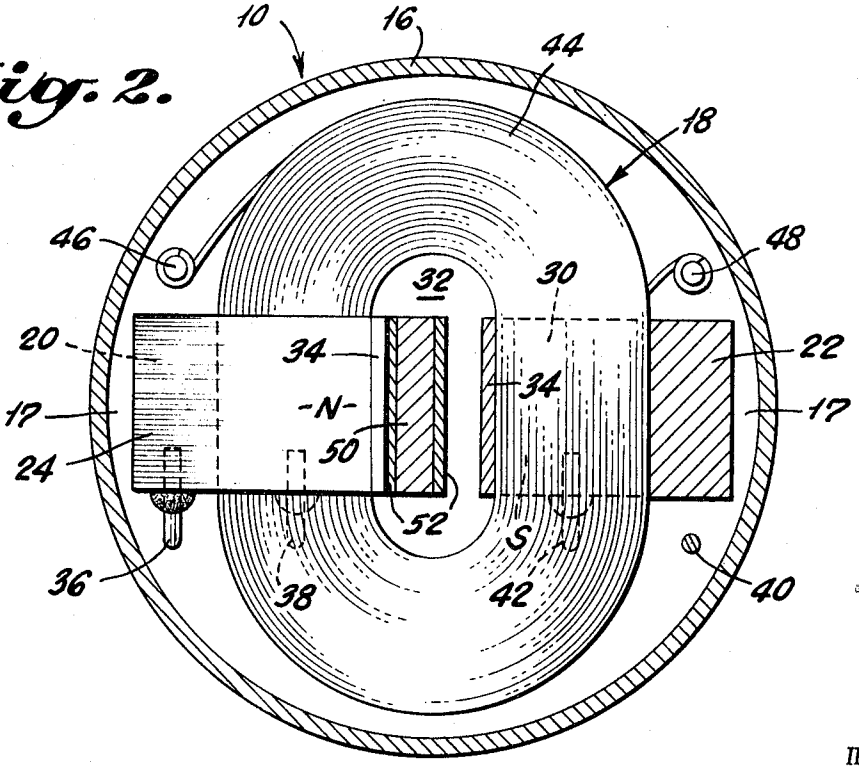


Fig. 2.



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May 26, 1970 P. E. UGON 3,514,728

FREE VANE MAGNETIC CIRCUIT

Filed Nov. 3, 1967 3 Sheets-Sheet 2

Fig. 4.

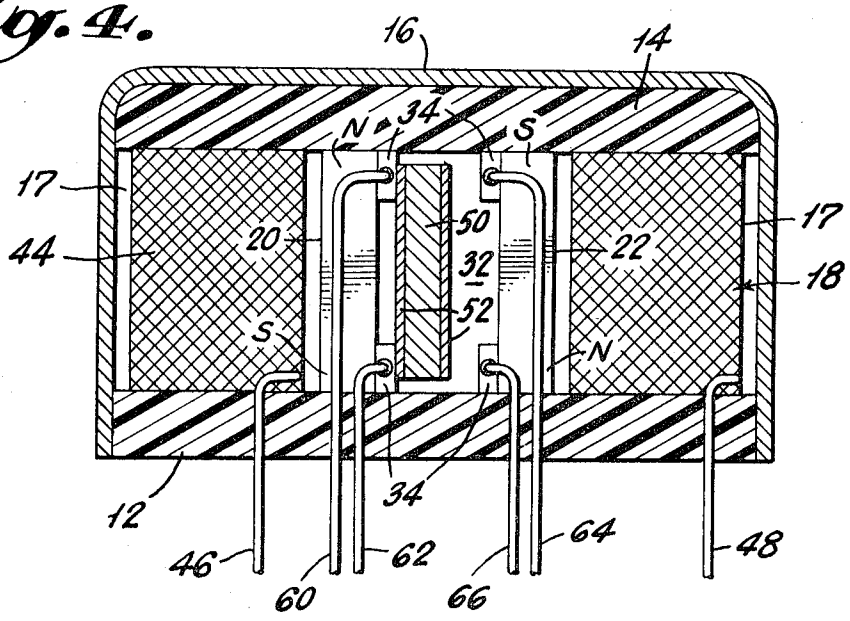
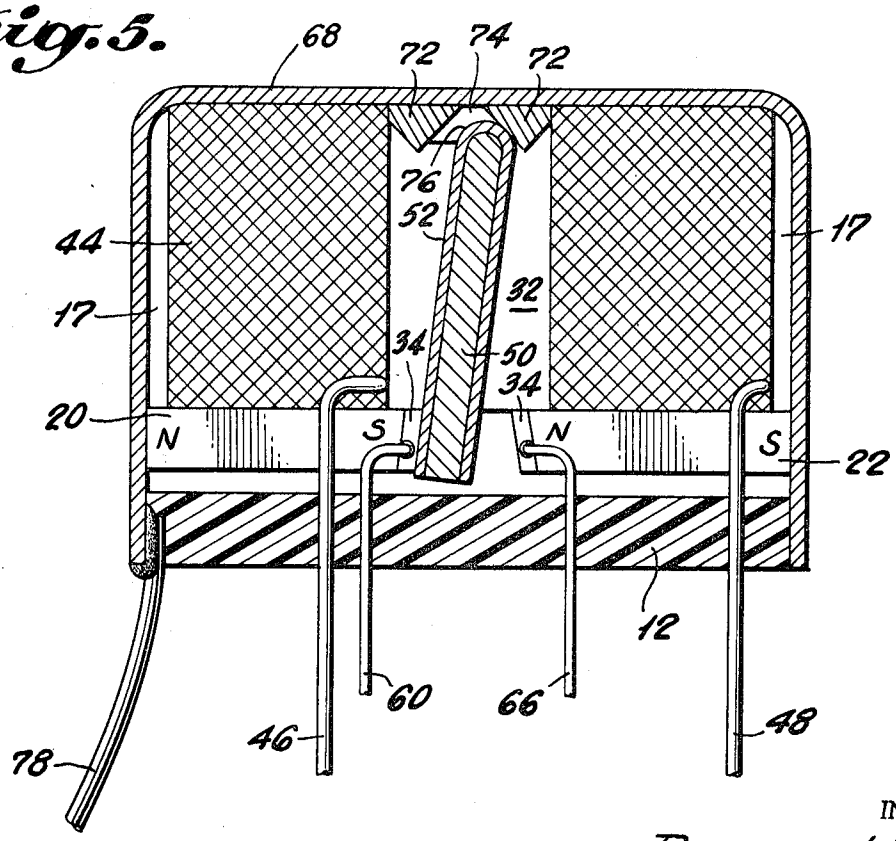


Fig. 5.



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May 26, 1970 P. E. UGON 3,514,728

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Filed Nov. 3, 1967 3 Sheets-Sheet 3

Fig. 7.

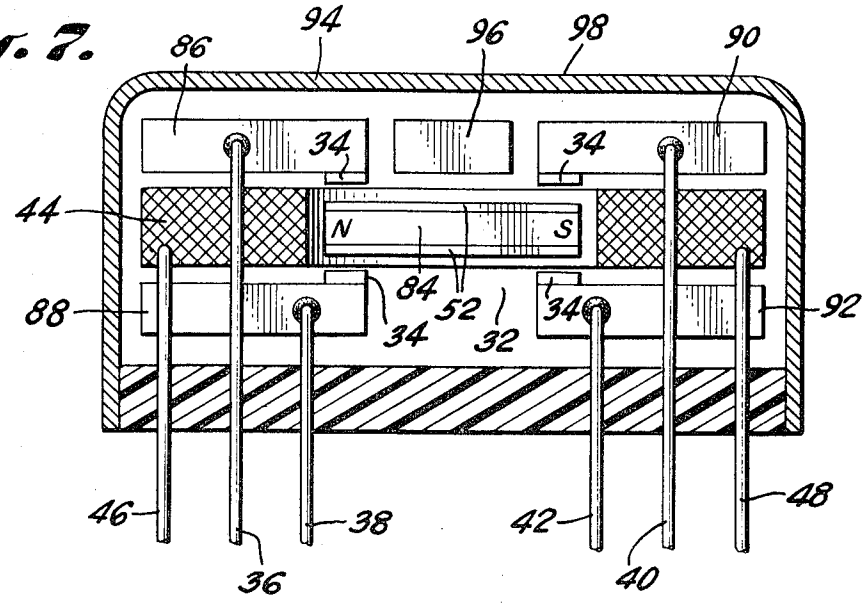
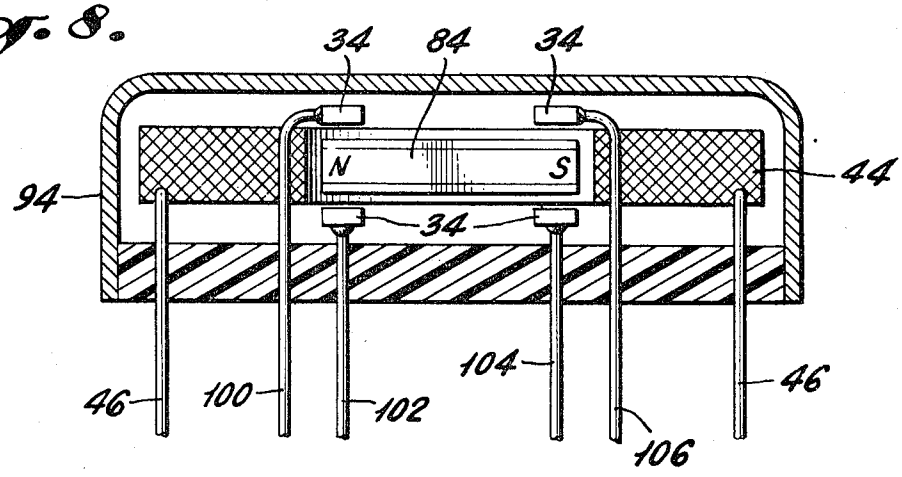


Fig. 8.



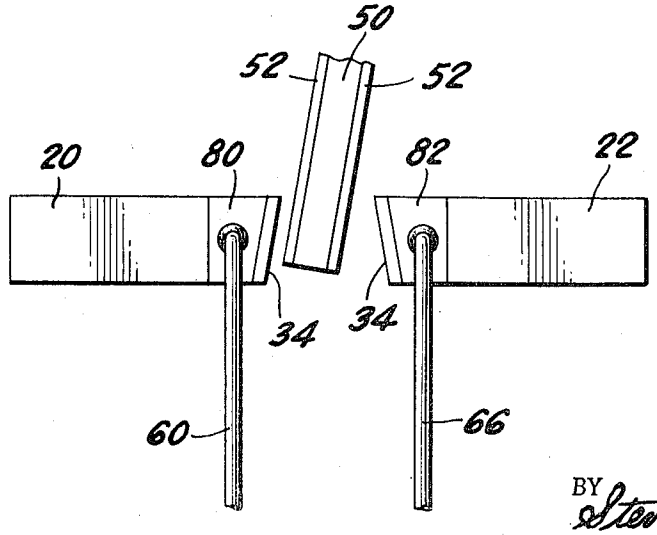


Fig. 6.

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3,514,728

FREE VANE MAGNETIC CIRCUIT

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Int. Cl. H01h 9/00
U.S. Cl. 335—179 12 Claims

ABSTRACT OF THE DISCLOSURE

An electromagnetic switching apparatus including electromagnetic means defining an armature housing cavity and having at least two spaced stops each formed of electrically conductive material. Means are also included providing a low reluctance path outside the cavity from one stop to the other and one section of the path is electrically nonconductive to electrically isolate the stops. A coil is provided to vary the magnetic field conditions within the cavity in accordance with an operating signal applied thereto. Each stop is electrically connected to a utilization circuit. An armature of magnetic material is provided within the cavity and either the armature or the electromagnetic means includes a permanent magnet. The armature is freely movable and floating within the cavity to operatively engage both said stops and disengage and move away from at least one of the stops in response to the magnetic field conditions developed by the control signal. The armature has an outer layer of electrically conductive material to contact and electrically connect the stops when the armature engages therewith. Either one or both of the stop material or the armature outer layer material has high reluctance to provide a high reluctance but electrically conductive material extending from the magnetic part of the armature to the low reluctance path when the armature engages said stops.

BACKGROUND OF THE INVENTION

The present invention relates to free vane electromagnetic circuits such as relays or the like and more particularly to such devices wherein the poles of the magnetic circuit are electrically isolated from the rest of the magnetic circuit which closes the magnetic path between the poles and wherein a nonmagnetic but electrically conductive material extends from the magnetic parts of the armature to each respective (effective) pole when the armature is in the magnetically closed position.

Free vane electromagnetic relays and the like have been known for several decades. By virtue of the elimination of armature pivots, bearings, and other like supports, these free vane devices, in principle, provide switching arrangements in less volumetric space than is required for conventional relays of the non free vane type. However, known free vane relays of the type described have not been free of problems which have limited the degree of miniaturization obtainable with conventional designs. For example, prior free vane devices include at least a pair of electrical connections or stops arranged within the armature cavity. These stops are physically spaced from the ends of the pole shoes primarily to prevent the armature from contacting the pole shoes and thereby creating magnetic hysteresis problems and to assure electrical isolation between the associated stops. The space between each stop and the respective pole shoe is conventionally filled with air or insulating material such as paper or the like.

In view of the growing present demands for miniaturization of these devices, there is an important need in the art to miniaturize these devices even further than have been possible with conventional designs. The present invention provides a new and improved arrangement which affords greater miniaturization than heretofore possible. Briefly stated, the invention for the first time provides a device of the type described wherein the electrically conductive contacts or stops are attached directly to the poles or pole pieces thus permitting a reduction in the volume necessary for the armature cavity. At least part of the magnetic circuit outside the cavity includes an electrical nonconducting section to electrically isolate one stop from the other. The armature includes a body of magnetic material and at least an outer layer of electrically conductive material to make electrical connection between stops when the armature engages therewith. In order to prevent problems due to magnetic hysteresis (such as armature sticking), either the stop material or the armature conductive layer or both is formed of nonmagnetic material so that when the armature is closed, a *nonmagnetic* but *electrically conductive* safety gap extends from the magnetic part of the armature to the pole or pole pieces.

It is therefore an object of the invention to provide a free vane electromagnetic relay or the like which obtains the advantages and avoids the problems outlined above.

Other and further objects of the invention will become apparent with the following detailed description of the embodiments when taken in view of the appended drawings in which like characters refer to like structure and in which:

FIG. 1 is a diagrammatic illustration of a vertical section through one embodiment of the invention.

FIG. 2 is a horizontal section taken along line 2—2 of FIG. 1.

FIGS. 3, 4 and 5 are views similar to FIG. 1 illustrating further embodiments of the invention.

FIG. 6 is a partial exploded view of a modification of certain parts of the embodiments of FIG. 5.

FIGS. 7 and 8 are views similar to FIG. 1 illustrating additional embodiments of the invention.

With reference to FIG. 1, a switching device generally indicated as **10** according to the invention includes a pair of spaced electrical nonmagnetic insulators **12** and **14** positioned within a suitable housing or can **16**. The electromagnetic apparatus generally indicated as **18** is supported within can **16** between insulators **12** and **14**, and includes a pair of diametrically positioned permanent magnets **20** and **22** which in this example are formed of ferrite material which, as is commonly known, is electrically nonconductive. Pairs of electrically conductive magnetic pole pieces **24**, **26** and **28**, **30** extend from respective poles of magnets **20** and **22** toward each other and terminate to provide an armature housing cavity **32**. A spacer **17** of suitable material separates the can **16** from the electromechanical assembly **18**, for example, spacer **17** may be an air space or filled with a potting material. Each pole shoe facing cavity **32** is coated with an electrically conductive, nonmagnetic material **34** which acts as the electrical contact or stop for the armature as described below. Stops **34** are preferably formed of silver; however, metals such as nickel may be suitable but less efficient than silver. It can be seen that each stop **34** is electrically isolated from its associated stop through the magnetic path defined outside the cavity by virtue of the electrically nonconductive material forming magnets **20** and **22**. Moreover, since each magnet electrically isolates the pole pieces in this low reluctance path, electrical connections to the stops **34** are preferably made through leads **36**, **38**, **40**, **42** which are connected to the respective pole piece as shown by suitable solder connection or the

like. The operating coil **44** is wound about cavity **32** generally as shown and the operating signal is applied thereto through lead connections **46** and **48**.

The armature **50** floats in cavity **32** and is dimensioned to simultaneously engage associated pairs of stops **34** depending upon the magnetic field conditions generated by coil **44**. Armature **50** is formed of a suitable magnetic material such as soft iron and has outer layers of electrically conductive, nonmagnetic material **52** such as silver or the like.

In operation, it can be seen that when armature **50** is moved by coil **44** to engage one pair of stops such as shown in FIG. 1, the gap between the magnetic part of armature **50** and each magnetic pole piece **24** and **26** is completely filled with electrically conducting, nonmagnetic material, i.e., the material forming each stop **34** and the respective outer armature layer **52**. In this way, the arrangement as disclosed avoids magnetic hysteresis problems and effectively eliminates non current carrying spaces by filling the safety gap between armature **50** and the pole pieces when closed with electrically conductive-nonmagnetic contact material.

It will be appreciated that it may be possible to eliminate the outer nonmagnetic layers **52** of armature **50** and still practice the invention. In this case, electrical connection between stops **34** is made through the armature soft iron body **50** while the magnetic safety gap is provided by the electrically conductive nonmagnetic material of stops **34**, which would have a suitable thickness to give the desired results. Similarly, stops **34** can be formed by the pole shoes so that the nonmagnetic, conductive layers **52** of armature **50** provide the aforementioned results.

A second embodiment of the invention is illustrated in FIG. 3 wherein ferrite magnets are replaced by metallic magnets **54** and **56** which, of course, are electrically conductive. In this embodiment, associated pairs of stops **34** are electrically isolated by thin insulating sheets **58** covering the entire surface of the respective poles thereby separating the pole and pole piece. Sheets **58** may be applied at one or both poles of each magnet **54** and **56**. The thickness of sheet **58** should be suitably small so as to add only negligible reluctance to the magnetic circuit.

The embodiment shown in FIGS. 1, 2 and 3 have been built in accordance with the invention and fitted in a can **16** having dimensions no bigger than 8 mm. in diameter and a height of 6 mm. Smaller dimensions are anticipated.

The embodiment of FIG. 4 provides an arrangement of fewer parts than the aforementioned embodiments of FIGS. 1 and 2. Specifically, ferrite magnets **20** and **22** are located contiguous to the armature housing cavity **32** and contacts **34** are attached directly to the magnet poles. Magnets **20** and **22** being formed of ferrite material or the like provide electrical isolation between associated pairs of stops **34**. Coil **44** is wound about the entire cavity and magnet assembly as shown. The thickness of stops **34** are sufficient to permit attachment of leads **60**, **62**, **64** and **66**. Furthermore, since magnets **20** and **22** are nonconducting, efficient production methods can be used to extend these leads to stops **34** by coating the leads directly on magnets **20** and **22**. Electrical deposition of the lead and contact material may be obtained by any suitable means such as cathole deposition or electrolysis deposition now commonly used in the printed circuit board art.

Normally, problems would result from the close positioning of the magnet and armature as provided in the embodiment of FIG. 4. However, such close positioning is efficiently achieved herein by virtue of the large difference in permeability between the ferrite magnets and the iron armature body. Specifically, the iron permeability is several thousand times greater than that of each ferrite magnet. Therefore, the magnetic characteristics of armature **50** is modulated to a much greater extent than are magnets **20** and **22** in response to changing field conditions induced by coil **44**. Furthermore, if we compare this design to the embodiments of FIGS. 1 and 3, the mutual proximity of leads **60**, **62** and **64**, **66** reduces the induction therein in response to excitation of the operating coil **44**.

The embodiment of FIG. 5 provides an arrangement wherein the magnetic circuit also serves as part of the electric circuit. This embodiment includes a housing or can **68** which is formed of magnetic material. A pair of ferrite magnets are arranged on opposite sides and near one end of cavity **32** and are oriented with their poles in mutual horizontal alignment. The poles of these magnets furthest from cavity **32** are connected to opposite sides of can **68** so that the latter serves as a pole piece for each magnet. Operating coil **44** is wound about cavity **32** generally as shown. A pair of depending abutments or stops **72** form a groove **74** which extends into the top end of cavity **32**. Stops **72** are preferably made of silver or other nonmagnetic-electrically conductive material.

The pole of each magnet **20** and **22** facing cavity **32** is inclined and coated with electrically conductive nonmagnetic material such as silver to form stops **34**. Armature **50** floats in cavity **32** and includes electrically conductive nonmagnetic outer layer **52** which covers both side faces and defines a rounded top **76** for the soft iron body part of armature **50**.

In operation, stops **34** are electrically isolated from each other since they only contact the ferrite material. When armature **50** is moved under the influence of coil **44** to close one of the magnetic circuits such as the one illustrated, the bottom of armature **50** is pulled flush against the inclined face of the respective stop **34**. The motion of armature **50** is generally arcuate while the rounded top **76** remains in electrical contact with stops or electrical contacts **72**. In this way, electrical connection is made through stop **34** associated with magnet **20**, layer **52**, stop **72**, and can **68** to the electrical lead **78** electrically connected thereto. Again, the magnetic part of armature **50** when closed with one of the magnets is separated from the magnet pole only by electrically conductive, nonmagnetic material.

A modification of the contact arrangement of the embodiment of FIG. 5 is illustrated in FIG. 6. Specifically, pole pieces formed of soft iron **80** and **82** are secured between the ferrite magnetic poles and the respective electrical stop **34**. Since pole pieces **80** and **82** are electrically conductive, the electrical leads to the utilization circuit are taken from these pole pieces thereby simplifying fabrication.

A further modification (not shown) comprises ferrite magnets **20** and **22** being replaced with electrically conductive ones but each with its outer pole separated from can **68** by a thin electrical insulator. This modification employs an arrangement technique similar to that disclosed herein in connection with FIG. 3.

The embodiments as disclosed above may have a pair of permanent magnets poled in opposite directions so as to provide a bistable working device. Alternatively, if the magnets are poled in the same sense, i.e., north-to-north, south-to-south, the device operates as a flip-flop which changes conditions for each pulse of the same polarity. Thereby, if a series of pulses of the same polarity are applied to the operating coil the armature moves to engage the opposite pair of contacts for each pulse applied notwithstanding the pulse being of the same polarity. Furthermore, in the above embodiments, if one magnet is replaced by a soft ferrite formed of a permeable nonmagnetic material, and which is nonpolarized, the device operates in a monostable mode.

Relay devices including several sections of the embodiments depicted in FIGS. 1, 3 and 5 are also possible. In this case, the outer can is elongated and a plurality of stages of one of the embodiments are spaced one next to the other throughout the length of the can. In this arrangement, only two opposite magnets extending substantially the length of the can would be needed to polarize magnetically the poles of all individual stages at the same time. The individual function of each of these devices or

stages will not effect or is not effected by other stages within the can and each stage effectively operates its own armature. Also possible is such an elongated device having a plurality of stages with a single operating coil extending through all stages. In this case, a single operating current applied to the coil effects the positioning of all armatures of all stages. Further variation includes a can having, for example, five stages with, for example, two operating coils, one coil driving three of the stages and the other coil acting on the other two stages. Two different power supplies are provided each controlling opposite ones of the operating coils.

Turning now to the embodiment of FIG. 7, there is illustrated an electromagnetic relay in which the free vane armature comprises a ferrite or soft iron permanent magnet **84** having opposite faces coated with layers of nonmagnetic electrically conductive material **52** such as silver or the like. The pole pieces **86, 88, 90** and **92** are spaced to form cavity **32** within which armature **52** floats. Electrical contacts or stops **34** are attached to the respective pole piece ends nearest cavity **32** and aligned with the poles of magnet **84**. The pole pieces and consequently the stops **34** are electrically insulated from each other and electrical lead connections are made to these pole pieces in the manner described. Coil **44** is wound about the cavity **32** between the pole pieces so as to generate electromagnetic fields to magnetiz pole **86** opposite from pole **88** and pole **90** opposite from pole **92**. The magnetic circuit for poles **86** and **88** and poles **90** and **92** is completed through the associated parts of can **94** which is formed of magnetic material such as soft iron or the like. If desired, the magnetic circuit can be completed through a magnetic soft iron part (not shown) connecting the outer ends of the pole pieces and which part is separate from the can **94**. A complementary magnetic piece **96** is positioned outside cavity **32** between pole pieces **86** and **90** so as to move magnet **84** in contact with stops **34** on pole pieces **86** and **90** to establish an initial position for the magnet when the actuating current is removed from coil **44**. If desired, part **96** can have any suitable position and in some instances its function may be provided by the bottom **98** of the can itself. Suitable insulating material may be provided to support the assembly parts within can **94** where necessary.

In operation, when no current is applied to coil **44**, the armature experiences a force in the direction of part **96** by virtue of the lower reluctance path established on that side of cavity **32** than on the other. Armature **84** moves to close the contacts **34** of pole pieces **86** and **90**. When energizing current is applied to coil **44**, the induced magnetic field in the pole pieces repels one end of armature **84** so that it moves away to contact the stop on one of the pole pieces **88** and **92**. For example, armature **84** may be actuated to connect the stops on pole pieces **86** and **92** by a signal to coil **44** of one polarity and to connect the stops on pole pieces **88** and **90** by a signal of opposide polarity. Whenever the coil signal is removed, armature **84** returns to its initial position engaging pieces **86** and **90**.

In the embodiment of FIG. 8, with can **94** formed of magnetic material, it is possible to eliminate the pole pieces as compared to the embodiment of FIG. 7. In FIG. 8, the magnetic armature is still effected by the electromagnetic fields developed by coil **44** which are concentrated by the magnetic can (such as soft iron) **94**. The electric contacts or stops **34** are supported at the ends of leads **100–106** having suitable dimensions for strength purposes. Of course, electrical insulation may be applied within can **94** where necessary or desirable to secure the positions of stops **34**. Armature movement and initial positioning is the same as described for the embodiment of FIG. 7.

Thus, there has been described a new and improved electromagnetic relay which achieves results not heretofore possible in the art. It will be understood that the various embodiments hereof are only disclosed by way of examples and other and further modifications of the invention may be made without avoiding the spirit or scope thereof. For example, the invention may be used in other than free vane devices such as reed switch relays and the like. In that case at least one of the reeds is coated with the nonmagnetic, electrically conductive layer so that when the reeds engage, the layer material thickness extends from one magnetic reed part to the other magnetic reed part.

What is claimed is:

1. An electromagnetic switching apparatus comprising electromagnetic means defining an armature housing cavity and having at least two spaced stops each comprising electricly conductive material, means providing a low reluctance path outside the cavity from one stop to the other and one section of the path being electrically nonconductive to electrically isolate the stops, said electromagnetic means further including a coil to vary the magnetic field conditions within the cavity in accordance with an operating signal applied thereto, a pair of electrical connections each coupled to an opposite stop and being adapted to be operatively connected to a utilization circuit, a magnetic armature, one of said electromagnetic means and said armature including a permanent magnet, said armature being freely movable and floating within said cavity to operatively engage both said stops and disengage and move away from at least one of said stops in response to the magnetic field conditions developed by said control signal, said armature having an outer layer of electrically conductive material to contact and electrically connect the stops when said armature engages therewith, and at least one of said layer and said stop material being of high reluctance to provide a high reluctance but electrically conductive material extending from the magnetic part of the armature to the low reluctance path when the armature engages said stops.

2. The apparatus of claim **1** wherein said electromagnetic means comprises the permanent magnet having one pole magnetically coupled to one stop and the other pole magnetically coupled to the other stop, and wherein both said layer and said stop material have high reluctance characteristics.

3. The apparatus of claim **2** wherein the permanent magnet is spaced from said cavity and pair of stops, a pair of electrically conductive magnetic pole pieces each extending from the region near opposite poles of said magnet to opposite stops and being electrically connected thereto, each of said electrical connections being connected to the associate pole piece, and said pole pieces being electrically isolated from each other by said one section of said low reluctance path between the stops.

4. The apparatus of claim **3** wherein said one section of the low reluctance path comprises the permanent magnet which is formed of magnetic but electrically nonconductive material.

5. The apparatus of claim **3** wherein the permanent magnet is formed of electrically conductive material and said one section of the low reluctance path includes a thin electrical insulator separating one of the pole pieces from the associated magnet pole.

6. The apparatus of claim **3** wherein the electromagnetic means further comprises a second pair of such stops arranged on the opposite side of said armature as said first-mentioned pair, a second permanent magnet spaced from the second stops, a second pair of such pole pieces extending from opposite poles of said second permanent magnet to opposite ones of said second stops and being electrically connected thereto to form a low reluctance path between said second stops outside said cavity and said electromagnetic means further including means forming one section of said last-mentioned low reluctance path which is electrically nonconductive to electrically isolate said second pole pieces, a second pair of such electrical connections each connected to opposite ones of said sec-

ond pole pieces, said armature including a second electrically conductive high reluctance outer layer facing the second stops, and said coil being wound generally symmetrically about said cavity to operatively move the armature to electrically connect said first-mentioned pair of stops in response to an operative signal applied thereto, and when the armature engages said second pair of stops the second outer layer and respective second stop extend generally continuously from the magnetic part of said armature to the low reluctance path extending between said second pair of stops.

7. The apparatus of claim **2** wherein said one section of the low reluctance path is formed by the permanent magnet which is formed of magnetic but electrically nonconductive material, said stops being attached to opposite poles of said permanent magnet, and said coil is wound about both said cavity and permanent magnet.

8. The apparatus of claim **2** wherein the permanent magnet poles are aligned with one armature end and generally parallel to the direction of armature movement, said coil being wound about said cavity and parts of the armature not aligned with the magnet poles, one stop being arranged between said one end of the armature and the nearest magnet pole and the other stop positioned to contact the armature near its other end, said first stop being shaped to pivot the armature about an imaginary axis when said one end is attracted thereto and to move the other armature end in the same rotational direction to engage the other stop.

9. The apparatus of claim **8** wherein a pole piece connects the magnetic pole facing away from the armature with the other stop and said permanent magnet is formed of electrical nonconductive material.

10. The apparatus of claim **9** wherein an electrically conducting pole piece extends from the magnet pole facing the armature and said one stop, and one electrical connection is connected to said last-mentioned pole piece.

11. The apparatus of claim **1** wherein the armature comprises the permanent magnet, a pair of pole pieces each connected to opposite ones of said stops and positioned within the flux fields developed by the coil and means spaced from one side of the armature to effect movement of the armature to a predetermined initial position relative said stops whenever the coil operating signal is terminated.

12. An electromagnetic switching apparatus, comprising a can formed of magnetic material, a coil wound within said can so as to form an armature cavity therein, an armature having opposite faces coated with a layer of electrically conductive and magnetically insulating material, said armature being a permanent magnet, magnetized in a direction perpendicular to the axis of the coil, two pairs of stops formed of electrically conductive material and each stop being supported in electrical isolation from the others, each pair being arranged on opposite sides of the cavity such that the armature electrically connects the stops upon engagement therewith in response to magnetic fields developed by operating signals applied to said coil.

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