Feb. 6, 1968 H. SAUER 3,368,170

POLARIZED ELECTROMAGNETIC RELAY

Filed March 3, 1966 4 Sheets-Sheet 1

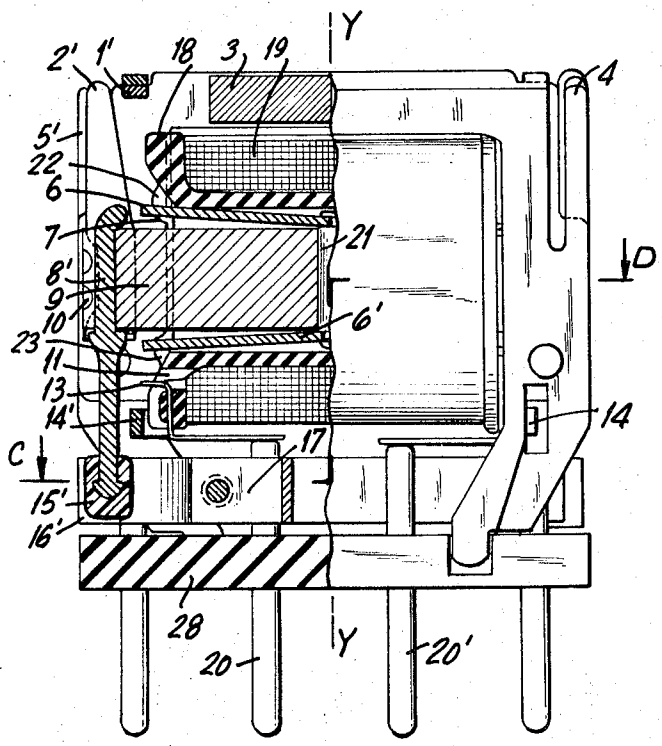


FIG. 2

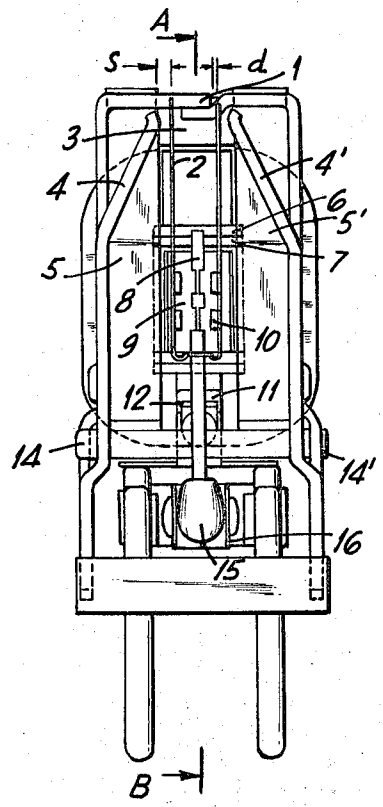


FIG. 1

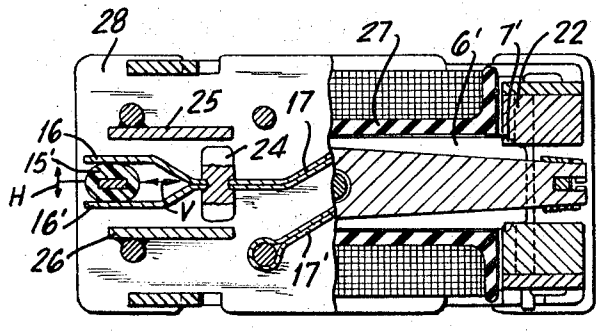


FIG. 3

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POLARIZED ELECTROMAGNETIC RELAY

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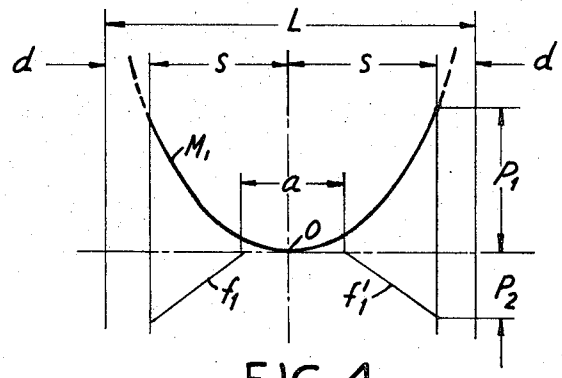


FIG. 4

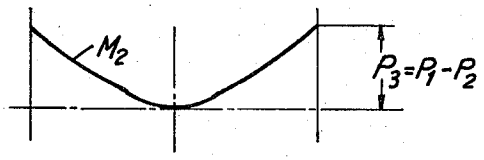


FIG. 5

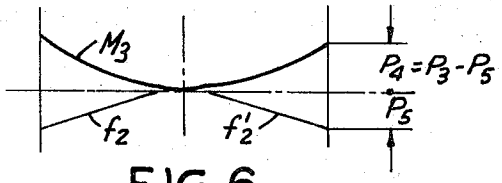


FIG. 6

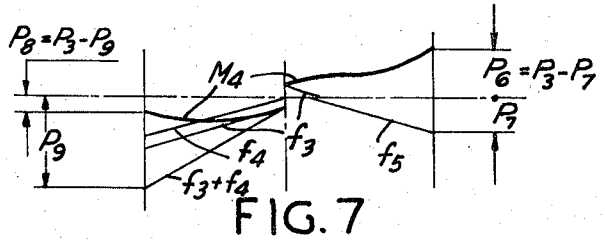


FIG. 7

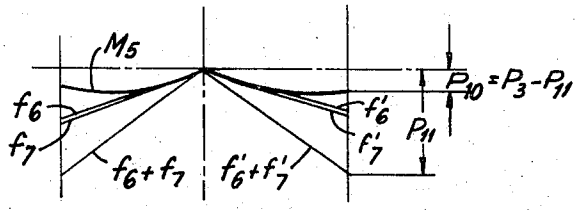


FIG. 8

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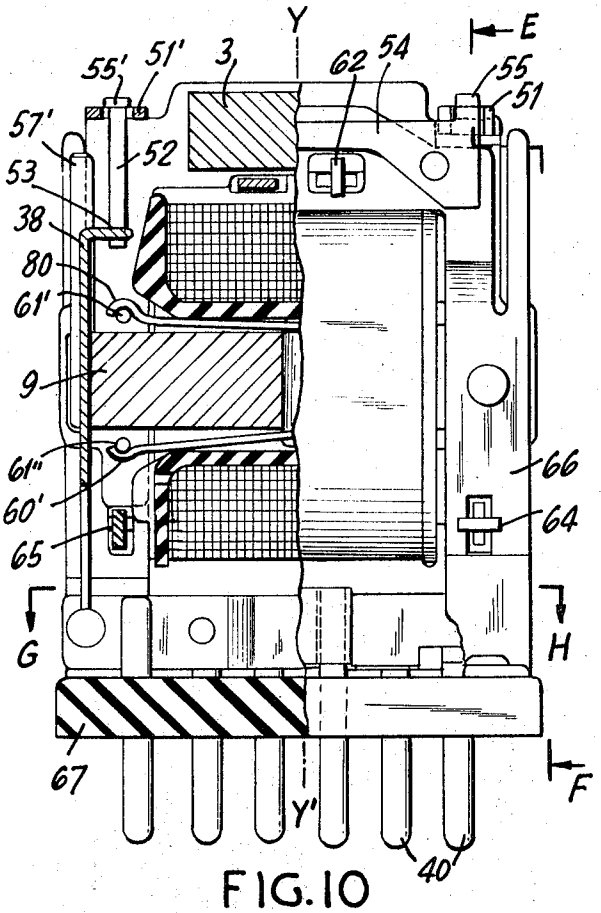


FIG. 10

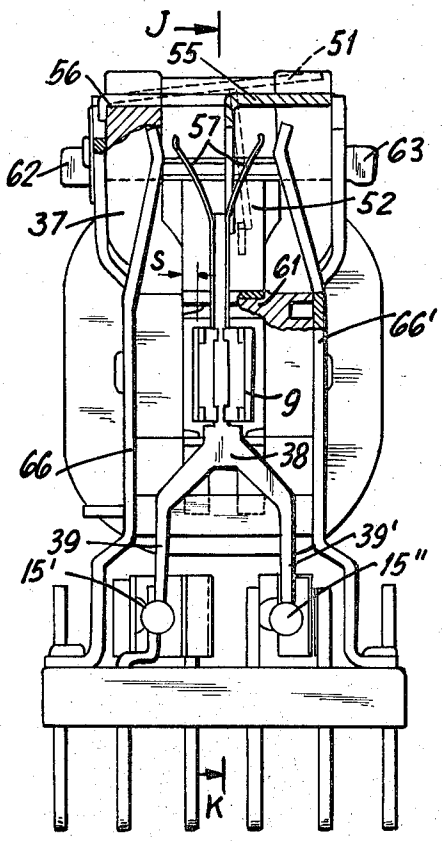


FIG. 9

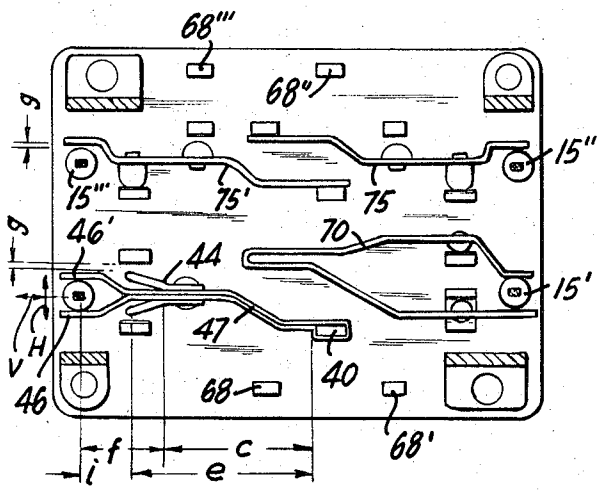


FIG. 11

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POLARIZED ELECTROMAGNETIC RELAY

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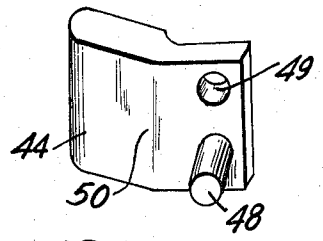


FIG.12

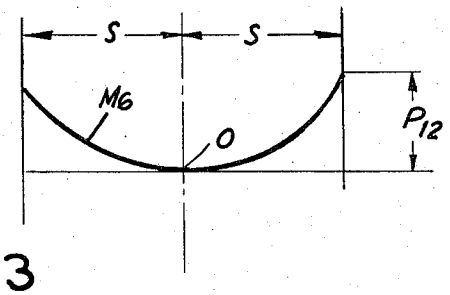


FIG.13

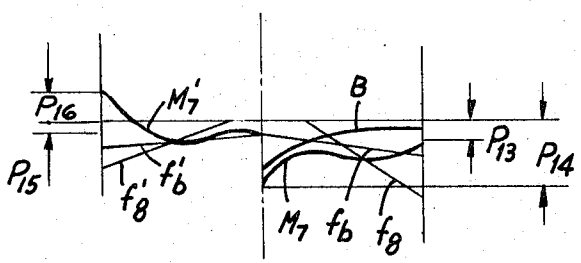


FIG.14

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3,368,170

POLARIZED ELECTROMAGNETIC RELAY

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Filed Mar. 3, 1966, Ser. No. 531,570
Claims priority, application Germany, Mar. 4, 1965, S 95,770
20 Claims. (Cl. 335—86)

ABSTRACT OF THE DISCLOSURE

A polarized electromagnetic relay is disclosed as including a permanent magnet structure including at least one permanent magnet and providing a polarized permanent flux path extending between a pair of opposite magnetic poles. The magnetizing winding is wound on a generally tubular spool or diamagnetic material, and a pair of relatively elongated bearing plates of diamagnetic material extend in laterally spaced parallel relation through the spool and have their ends supported in the permanent magnet structure. The armature extends through the spool, between these plates, and is swingably mounted on a bearing pin extending between the plates at substantially the center of gravity of the armature.

The opposite ends of the armature carry contact operators extending toward the base of the relay, and the lower ends of these operators are operatively associated with the free ends of contact springs carrying movable contacts selectively engageable with stationary contacts on the base. Adjusting springs are associated with each operator, and extend upwardly from the oposite ends of the armature. These springs, in one embodiment of the relay are so disposed that they serve as separators between the respective end of the armature and the associated magnetic poles. The springs may either be diamagnetic material or may be ferromagnetic material.

In another embodiment of the invention, pivotal bridges of paramagnetic iron are provided, and are spring biased, to short out a part of the permanent magnetic flux whereby to provide a stable position for the armature. In this latter embodiment of the invention, novel movable contacts are mounted on the contact springs. A further feature of the disclosure is the connection of the ends of the winding to spring metal strips which bear on pins mounted in the base, these pins serving as the connections of the magnetizing winding.

Background of the invention

This invention relates to electromagnetic relays and, more particularly, to a novel and improved polarized electromagnetic relay which, within the available magnetic strength of a permanent magnet, requires not more, or less, excitation for large contact forces than for small contact forces, and which permits the armature to occupy selectively one or more rest positions under the influence of adjusting springs, and which is furthermore adjustable as a center position relay without additional means, and in which center position relay, in the unexcited state, all the contacts are opened.

Polarized relays include at least one permanent magnet which either is provided with pole pieces or else lies between two pole pieces. The relays further include an armature mounted between these pole pieces or otherwise magnetically coupled thereto, as well as a coil which may be energized to operate the relay. The armature actuates one or more contacts either directly or through the medium of an actuating member.

It is known to provide a polarized relay with a compensating spring by means of which not only can dis-

symmetry of the permanent magnet circuit be compensated but also the required excitation be reduced. However, the excitation required is reduced in about the same degree as the contact pressure, and hence the contact reliabiilty and load carrying ability is reduced accordingly.

It is also known to provide polarized relays with elastic contact members in order to attain some contact friction and sequential operation of contacts so that several contacts can be actuated by a rigid armature. Although the forces resulting from the permanent magnet are stored by such a measure, this is so only in the relatively small zone of the contact motion possible with relays of this type. A particular disadvantage is the lack of ability to adapt to the force-distance curve of the magnet system. Other polarized relays having three rest positions of the armature use elastic members to compensate the permanent magnet forces, but must use greater excitation for high contact forces as compared to the excitation power required for small contact forces.

An object of the present invention is to provide a polarized electromagnetic relay which is free of the disadvantages of the prior art as mentioned above.

Another object of the invention is to provide a polarized electromagnetic relay which not only utilizes the play of forces from the magnet system with respect to minimum excitation power and maximum contact pressure but also permits different relay characteristics without additional expense.

A further object of the invention is to provide a polarized electromagnetic relay in which a storage of a portion of the available permanent magnet forces is effected in the contact springs.

Yet another object of the invention is to provide a polarized electromagnetic relay characterized by storage of a portion of the available permanent magnet forces in the contact springs and preferably utilizing, in addition, adjusting springs whereby the required excitation power decreases inversely with the contact pressure.

Yet a further object of the invention is to provide a polarized electromagnetic relay which is simple and inexpensive in construction, reliable in operation, and may have one, two or three rest positions, and which permits the use of a variety of contact arrangements.

For an understanding of the principles of the invention, reference is made to the following description of typical embodiments thereof as illustrated in the accompanying drawings.

In the drawings:

FIG. 1 is an end elevation view of one form of polarized electromagnetic relay embodying the invention;

FIG. 2 is a side elevation view of the relay shown in FIG. 1, partly in section on the line A–B of FIG. 1;

FIG. 3 is a transverse sectional view of the relay shown in FIGS. 1 and 2, taken on the line C–D of FIG. 2;

FIGS. 4 through 8 are force diagrams graphically indicating the force-distance and spring characteristics;

FIG. 9 is an end elevation view, partly in section on the line E–F of FIG. 10, of another embodiment of polarized electromagnetic relay in accordance with the invention;

FIG. 10 is a side elevation view, partly in section of the line J–K of FIG. 9, of the relay shown in FIG. 9;

FIG. 11 is a transverse sectional view taken on the line G–H of FIG. 10;

FIG. 12 is a perspective view of a contact incorporated in the relay of FIGS. 9, 10 and 11; and

FIGS. 13 and 14 are force diagrams, similar to FIGS. 4–8, but related to the relay of FIGS. 9–11.

Referring first to the embodiment of the invention shown in FIGS. 1, 2 and 3, the relay is symmetrical with respect to the axis or plane Y—Y of FIG. 2 which per-

pendicularly bisects the armature at the axis of its pivot. This has the advantage that the magnetic attraction forces in both directions, as viewed from the illustrated position of the armature, are symmetrical.

An important feature of the invention is the provision of the adjusting springs 2, 2', each of which is supported from an actuating member 8 or 8', respectively. These springs, which are formed of diamagnetic material, serve not only as dividing or separating plates between the ferromagnetic armature 9 and the pole pieces 5, 5', but also for the different compensations of the permanent magnet forces.

Each actuating member 8 or 8' is supported in a recess or groove 10 in a respective end of the armature 9. The armature 9 is mounted, for swinging movement in a horizontal plane about its center of gravity, by means of an axle or pivot 21 extending between a pair of bearing plates 6, 6', of diamagnetic material and located inside the coil form 27 on which there is wound the armature magnetizing winding or coil 19. This has the advantage, among others, that a separate winding core is unnecessary, and the further advantage that the magnetic field of coil 19 acts on armature 9 without stray magnetic losses. With the mounting of the armature 9 in this manner, mounting of the winding 27 as well as of the entire magnetic system is effected with the parts being mechanically coupled. Such mechanical coupling is obtained by virtue of the fact that the horizontal positions of the armature bearing plates 6, 6' are fixed by the recessed inner end faces 22 and 23 of the pole pieces 5, 5' in cooperation with the ledges 7, 7'. Thus, the ends of the armature bearing plates 6, 6' are supported at a pre-set selected distance from the armature 9 by engagement with the ledges 7, 7'. The armature path or travel s is determined by the recessed ends of the bearing plates 6, 6' which are held between pole pieces 5, 5' under a predetermined pressure.

Coil or winding form 27 is additionally positioned by virtue of noses 18 on its flange and which are engaged between pole pieces 5, 5'. The permanent magnet structure or circuit is connected with the two frame halves 1, 1', which are connected mechanically with the pole pieces 5, 5' at the overlaps between the two frame halves and are also interconnected by the cross member 14, 14', preferably by spot welding. The permanent magnet 3, or a pair of permanent magnets 3, are arranged between pole pieces 5, 5' with the proper polarity.

Each contact actuating element 8, 8' has, at its lower end, a body or contact operator 15, 15', respectively, of dielectric material. Each operator 15, 15' is under initial spring tension by virtue of being engaged between the resilient tongues 16, 16' of a contact spring 17 as best seen in FIG. 3. Upon actuation of armature 9 in either direction from the neutral position, a contact 24 carried by a respective contact spring 17 will engage either a fixed contact 25 or a fixed contact 26, depending upon the direction of motion of the armature 9.

To simplify and facilitate the assembly coil form 27 has assembled therewith springs 12 and 13 which extend through and are imbedded in the material of the winding form, as best seen in FIG. 2. From FIGS. 1 and 2, it will be noted that at least one end of the winding extends through an aperture 11 in the adjacent flange of form 27, and is electrically connected, as by spot welding, brazing, or otherwise to the inner end of a respective spring 12 or 13. The outer or free ends of springs 12 and 13 contact the winding terminals 20 or 20' mounted in the base plate 28.

Referring to FIGS. 4 through 8, in FIG. 4, the force-distance curve of armature 9 under the influence of the magnetic circuit is indicated at M_1. The curve M_1 of FIG. 4 represents the force-distance curve without any compensation. The displacement force is plotted as the ordinate, and the deflection of the armature is plotted as the abscissa. The locus O of FIG. 4 corresponds to the

neutral armature position as represented in FIGS. 1, 2 and 3. It can be seen, from FIG. 4, that the force increases approximately with the square of the amplitude of the deflection, and in each direction from the central or neutral position 0.

The force P may be expressed by the following equation:

$$P=FSB^2/\mu L$$

where

F is the pole surface of the armature;
S is the armature path or travel distance as measured from the central position;
L is the total air gap including the thickness d of the separating plates or adjusting springs 2, 2';
B is the effective induction of the permanent magnet structure between the pole faces; and
μ is the permeability.

This means that at and in the immediate vicinity of the engaging points of armature 9 with pole pieces 5, 5', the displacement force P_1 is relatively great and usually increases at such a steep rate that even a slight change in the amplitude of movement of the armature effects a great difference in the restoring or displacement force. For this reason, it has been desirable to interpose, between armature 9 and pole pieces 5, 5', separating plates of a diamagnetic material, and such measures are customary in electromagnetic relays. In a polarized electromagnetic relay, the induction of the permanent magnet is reduced either by a partial demagnetization or by a partial and controllable magnetic bridging or shorting until the desired final force is attained. While the magnetic tolerances of the permanent magnets are thereby compensated, the efficiency of the permanent magnet system is reduced to an equal degree. Thus, upon excitation of the polarized relay, the final force is

$$P_E=FB/\mu(sB/d\pm\Delta B)$$

The induction ΔB due to the excitation circuit forms, with the induction B of the permanent magnet circuit, a product which, depending on the sign or direction of current in the winding 19, increases or decreases in the final force P_E. In order to actuate the armature from one limiting position to the other, the product $B\Delta B$ must be greater, and must have a different sign, than the factor sB^2/d.

Thereby, the force P_1 of FIG. 4 is reduced by the force P_2 as the two spring tongues 16, 16' (FIG. 3) act counter to the magnetic attraction direction on the bodies 15, 15' and thus on the armature 9. In FIG. 4, the distance a corresponds to the contact spacing, and the negatively directed spring characteristics f_1, f'_1 correspond to the spring constants of the spring tongues 16, 16'.

FIG. 5 illustrates a force-distance curve M_2 which is the force-distance curve M_1 of FIG. 4 with the negatively directed spring forces f_1 and f'_1 subtracted therefrom. Since the force P_3 actuating the armature 9 toward the pole pieces 5, 5' is much smaller than the force P_1, the required excitation of the winding 19 is correspondingly lower, and this is due also to the fact that the induction of the permanent magnet circuit has not been reduced in the invention relay, as compared with the prior art procedures mentioned above. Additionally, the force P_2 thus stored is used gainfully as the contact pressure for the duration of closure of the contacts.

Another advantageous feature is the compensation of the magnetic tolerances of the permanent magnets 3 through the pole piece cross section, which is magnetically saturated. Namely, the contact areas of the magnets with the pole pieces 5, 5' are very much greater than the cross sections of the pole pieces. If the adjusting springs 2, 2' are tensioned by bending of the flaps 4, 4' (FIG. 1), an additional compensation or storage of the force due to the permanent magnet is provided.

FIG. 6 illustrates the condition that the negatively directed spring characteristics f_2, f'_2 combined with the final spring force P_5 reduce the force-distance curve M_2 of FIG.

5 to the effective force $P_4=P_3-P_5$, the resultant curve being shown at M_3 in FIG. 6. This compensation reduces only the force with which the armature engages the pole pieces, and thus reduces the required coil excitation without influencing the contact pressure. It is therefore desirable to store as much force as possible in the spring tongues **16**, **16'** which determine the contact pressure, because, with increasing contact pressure reliability of the contact is increased and the contact resistance is decreased.

As is known, a spring constant is a third order function of the elastic length of a spring. Therefore, a small displacement of the operators **15**, **15'** in the direction of the arrow V of FIG. 3 will be sufficient to change substantially the steepness of the spring characteristics f_1, f'_1. Upon displacement of an operator **15**, **15'** in the actuating direction H of FIG. 3, the spring characteristics f_1 and f'_1, and thus the contact pressure, become unequal. If flap **4** is pressed against adjusting spring **2** to a greater extent then flap **4'** is pressed against adjusting spring **2'**, the non-excited armature **9** will engage the pole piece **5'**.

FIG. 7 shows this play of forces due to the initial tension of the two adjusting springs, in one direction of force, and in FIG. 7 these forces are represented by the spring characteristics f_3 and f_4. By virtue of these spring characteristics, the force-distance curve M_4 is brought into the negative zone on one half of the armature path of travel. The restoring force P_6 on the armature is the result of the difference P_3-P_7, while the force P_8 is located in the negative zone for the reason that the sum of the spring characteristics f_3+f_4 is greater at every point than in the portion of the force-distance curve M_2 lying in the positive zone. The force P_8 is equal to P_3-P_9.

If the adjusting springs **2**, **2'** are tensioned by bending the flaps **4**, **4'** to an extent such that they completely overcome the permanent magnet forces, the armature is maintained in the unexcited state at the neutral or central position between the pole pieces **5** and **5'**. As shown in FIG. 8, the force-distance path M_5 then lies entirely in the negative zone of the graph. In this case, it is desirable to maintain the force P_2 of FIG. 4 at a value much greater than the force due to the adjusting springs **2**, **2'** on the armature and which are represented in FIG. 8 by f_6, f_7 and f'_6 and f'_7. Also, in the invention relay, the contact forces can be determined not by the excitation of the winding **19** but by the spring constants of the contact spring ends **16**, **16'** and the deflection $s=a/2$. Thereby, the forces to be exerted by the excitation of the coil **19** can be maintained smaller than the contact pressure. The forces $P_8=P_3-P_9$ and $P_6=P_3-P_7$, as illustrated in FIG. 7, as well as the force $P_{10}=P_3-P_{11}$, as illustrated in FIG. 8, are smaller than the contact force P_2 illustrated in FIG. 4. If it is desired that the force-distance curve represented at M_1 in FIG. 4 rise more steeply, one or both adjusting springs **2**, **2'** may consist of ferromagnetic material, whereby the effective air gap L becomes smaller by the distance $2d$.

Due to the main outstanding feature of the invention that high contact pressures on the normally open and normally closed contacts can be exerted with the same or even with less operating power than low contact pressures, the relay can thus operate more contacts, with the same or with even less input power, than the one or two contact pairs illustrated in FIGS. 1, 2 and 3, provided the force of the permanent magnets **3** is sufficient. This does not present any problem, because the permanent magnet force depends only upon the size and/or the properties of the magnets and the cross section of the permanent magnet structure or flux circuit.

A relay having four different contact pairs is shown in FIGS. 9, 10, 11 and 12. Like the relay of FIGS. 1, 2 and 3, the relay of FIGS. 9 through 12 is symmetrical with respect to the axis or plane Y–Y' of FIG. 10. In this relay, each actuating element **38** is forked, and each leg **39**, **39'** can be adjusted independently of the other in both the H and V directions, as shown in FIG. 11.

The configuration of the contact **44**, in connection with the contact spring **47** and its tongues **46** and **46'**, is an important feature of the invention. Thus, the characteristic of the contact spring is important in the force characteristics of the magnetic system, as shown in FIGS. 5, 6 and 7. Furthermore, the conductor part of the contact spring, extending from the terminal **40** to the contact **44**, is only lightly stressed and furthermore has a double thickness relative to the thickness of the tongues **46** and **46'** which are used only mechanically. Due to this configuration, the deflection of each tongue is 8 times larger than it would be if the thickness of the tongues were twice that illustrated.

Another advantage is that each tongue is deflected in one direction only, and thus has a much longer life as compared with a tongue subjected to alternating bending strains. As compared with a known type of contact rivet such as shown at **24** in FIG. 3, the contact **44** shown in FIGS. 9 through 12 can be riveted in position after being subjected to gold or rhodium plating, because the surface of the contact area remains untouched. This means a plating cost for the springs of about one tenth that normally required.

Another advantage is that the contact **44** has its contact point spaced a greater distance from terminal **40** than is its shoulder **50**. As a result, the travel of contact **44** is greater than the travel of the contact **24** of FIG. 3 if the movement of actuator element **45**, the bending length f, and the other dimensions of spring tongues **16** and **46** are the same. Contact spring **47** is sandwiched between the two coined contacts **44** by virtue of the fact that each contact **44** has a pin or the like integral therewith and fitting through an aperture **49** through the other contact, with both pins **48** being riveted or headed over (FIG. 12).

If armature **9** is in the central or neutral position, neither contact **44** is closed. Referring to FIG. 11, a contact arrangement involving two normally closed contacts in the neutral position of armature **9** is illustrated by the contact spring **70**. If the actuator **15'** associated therewith moves in one direction H, one contact will open while the other contact will remain closed, and vice versa.

Another contact arrangement is illustrated by the contact springs **75** and **75'** and their associated contacts. If the armature moves in one direction, one actuator **15''** or **15'''** operates its associated contact spring **75** or **75'**, respectively, in a direction such as to change over the contacts associated with the contact spring, while the other contact spring remains in the illustrated position, and vice versa. If the relay is used single or bistable, only contact springs **47** will be mounted on the base **67** because of the features mentioned above, and further because no gap g is necessary for the contact arrangements **47**.

By reference to FIG. 8, it will be noted that the force maintaining the armature in the neutral position is zero. This means that there is no definitive neutral position, and furthermore, that the vibration resistance and shock resistance are very low. However, there is a substantial demand for a polarized relay having a definitive middle position from which the armature moves into one or the other of a pair of operated positions depending upon the direction of flow of current through the winding. It is known that such a definitive center position can be obtained by virtue of additional spring loading of the armature as shown, for example, in German Patents Nos. 1,120,595, 1,130,924 and 1,125,547. Aside from the fact that all of these known applications involve an arrangement in which the permanent magnet is carried by the armature, thus providing a permanently polarized armature, there are other disadvantages. Thus, either only one contact pair can be operated, or there is no possibility of adjusting the magnetic force other than by change of the contact pressure, or else six different adjusting means and operations are required for one change-over and one centrally positioned contact.

By contrast, a simple and more effective solution is shown in FIGS. 9 and 10. This solution involves the two bridges 51 and 51' which have identical shapes. These bridges are formed of paramagnetic iron and shorten, in accordance with their cross section, a part of the permanent magnet flux and thus use this part of the attractive force for a third stable position of the armature where the part 53 of the actuator 38 touches the part 52 of a bridge 51, namely in the central position of the armature.

FIG. 9 also shows, in dotted lines, one bridge 51 after the armature has been operated into one operated position. If the armature moves into the other operated position, the bridge 51 remains in the attractive position while the bridge 51' opens in the same way as indicated by the dotted line position of bridge 51.

Bridges 51 and 51' are maintained in position by a single leaf spring 54 effective on both bridges. This leaf spring is formed with two springs 55 and 55' which keep the bridges 51 and 51' in a pre-set position and also spring load the bridges, additionally, if this is necessary. If the bridges 51, 51' are formed from a diamagnetic material such as brass, they are then maintained in position solely by the spring loading due to springs 55 and 55'. The bearing edge 56 of each pole shoe 37 is coined to better define the bearing point of the associated bridge 51 or 51'. Bridges 51 and 51' are incorporated in the relay solely for assuring a definitive middle or neutral position of armature 9.

The force characteristic of a relay using the bridges 51 and 51' is illustrated in FIG. 14. FIG. 13 shows force-distance characteristic M_6 representing the attractive force of armature 9 due to the permanent magnet flux, as reduced due to the spring constants of four contact springs 47 but without any bridge.

In FIG. 14, the force-distance characteristics of an iron bridge 51 is indicated at B, the characteristics of the springs 55, 55' at f_b, f'_b, and the characteristics of the adjusting springs 57, 57' at f_8, f'_8. The force-distance line M_7 of FIG. 14 is the resultant of the force-distance line M_6 and the forces f_b, f_8 and B of FIG. 13, while the force line M'_7 is the resultant of the forces M_6, f'_b, f'_8. The force-distance characteristic M'_7 differs from the force-distance characteristic M_7 and illustrates the condition wherein a bridge of diamagnetic material, such as brass, is used, and wherein the pre-tension of the springs 57, 57' is different. It is a normal condition that the two parts of the force-distance curve on opposite sides of the center line are identical or mirror copies of each other, so that only half of each curve M_7 of M'_7 has been shown in FIG. 14.

It should be understood that the force P_{13} moves the armature, when the latter is not energized, from one pole engaging position to the center position with increasing force as indicated by the line M_7. In order to operate the armature from the center position to the "P_{14}—counteracting side," more operating power or excitation is required than for operation to the "P_{15}—counteracting side." The force P_{16} is positive, which means that the armature, when not energized, engages the pole shoe with the force P_{16} and can be moved into the center position by energizing the relay winding with a certain polarity and with a certain intensity of current or excitation. If the exictation power is not great enough to overcome the force P_{14}, the armature remains in the center position, and also if the excitation of the coil is interrupted when the armature reaches the center position. However, if the excitation is strong enough to overcome the force P_{14}, the armature moves to the other pole shoe engaging position and returns to the center position after excitation is interrupted.

The relay of FIGS. 9, 10, and 11 differs slightly from that shown in FIGS. 1, 2 and 3. Thus, the bearing blades 60 and 60' for armature 9 are maintained in position by eight coined studs 61, 61'. The relay is assembled by twisting the legs 62, 63, 64 and 65 of the frame part 66, 66' after extension of these legs through apertures in the frame parts 66, 66'. The header 67 is preferably made from oxydceramic, or may be molded of a suitable synthetic resin plastic composition material, and is provided with four coil terminals 68, 68', 68'' and 68'''. It should be noted that the shape of the adjusting springs 57, 57' is similar to the shape of the corresponding springs shown and described in U.S. patent application Ser. No. 492,451, filed Mar. 7, 1955.

While specific embodiments of the invention have been shown and described in detail to illustrate the application of the principles of the invention, it should be understood that the invention may be embodied otherwise without departing from such principles.

What is claimed is:

1. A polarized electromagnetic relay comprising, in combination, means, including at least one permanent magnet, forming a permanent magnet structure providing a polarized permanent magnet flux path extending between a pair of opposite magnetic poles; a magnetizing winding wound on a diamagnetic tubular form; a paramagnetic armature extending through said form; a pair of bearing plates of diamagnetic material each extending through said form along a respective one of a pair of opposite longitudinal sides of said armature and fixedly positioned in said permanent magnet structure; said armature being swingably mounted on a bearing pin extending between said plates at substantially the center of gravity of said armature, and said armature swinging in one direction or the other in accordance with the direction of excitation of said winding; at least one contact spring, having a free end, displaceable by said armature in accordance with the excitation of said winding, and a fixed end; and at least one movable contact carried by said contact spring intermediate the ends of the latter and cooperable with a fixed contact; a portion of the permanent magnet flux force being stored in said contact spring during operation of said armature responsive to excitation of said winding, whereby the required excitation is inversely related to the resultant contact pressure.

2. A polarized electromagnetic relay, as claimed in claim 1, including adjusting spring means operatively associated with said armature and deflected during operation of said armature responsive to excitation of said winding, a portion of the permanent magnet flux force being stored in said adjusting spring means to assist in the reduction of the required excitation without change of the contact pressure.

3. A polarized electromagnetic relay comprising, in combination, means including at least one permanent magnet, forming a permanent magnet structure providing a polarized permanent magnet flux path extending between a pair of opposite magnetic poles; a paramagnetic armature; means swingably mounting said armature between said poles; a magnetizing winding operatively associated with said armature, said armature swinging in one direction or the other in accordance with the direction of excitation of said winding; at least one contact spring, having a free end, displaceable by said armature in accordance with the excitation of said winding, and a fixed end; at least one movable contact carried by said contact spring intermediate the ends of the latter and cooperable with a fixed contact; a portion of the permanent magnet flux force being stored in said contact spring during operation of said armature responsive to excitation of said winding, whereby the required excitation is inversely related to the resultant contact pressure; and adjusting spring means operatively associated with said armature and deflected during operation of said armature responsive to excitation of said winding, a portion of the permanent magnet flux force being stored in said adjusting spring means to assist in the reduction of the required excitation with increasing contact pressure;

said adjusting spring means being formed of a diamagnetic material and interposed between said armature and the faces of said magnetic poles to serve as separation elements between said armature and said faces.

4. A polarized electromagnetic relay, as claimed in claim 2, in which said adjusting spring means is adjustable to set the rest position of the armature either at a respective magnetic pole face or midway between the two pole faces.

5. A polarized electromagnetic relay comprising, in combination, means including at least one permanent magnet, forming a permanent magnet structure providing a polarized permanent magnet flux path extending between a pair of opposite magnetic poles; a paramagnetic armature; means swingably mounting said armature between said poles; a magnetizing winding operatively associated with said armature, said armature swinging in one direction or the other in accordance with the direction of excitation of said winding; at least one contact spring, having a free end, displaceable by said armature in accordance with the excitation of said winding, and a fixed end; at least one movable contact carried by said contact spring intermediate the ends of the latter and cooperable with a fixed contact; a portion of the permanent magnet flux force being stored in said contact spring during operation of said armature responsive to excitation of said winding, whereby the required excitation is inversely related to the resultant contact pressure; and adjusting spring means operatively associated with said armature and deflected during operation of said armature responsive to excitation of said winding, a portion of the permanent magnet flux force being stored in said adjusting spring means to assist in the reduction of the required excitation with increasing contact pressure; said adjusting spring means being of ferromagnetic material and being interposed between said armature and the faces of said magnetic poles.

6. A polarized electromagnetic relay comprising, in combination, means including at least one permanent magnet, forming a permanent magnet structure providing a polarized permanent magnet flux path extending between a pair of opposite magnetic poles; a paramagnetic armature; means swingably mounting said armature between said poles; a magnetizing winding operatively associated with said armature, said armature swinging in one direction or the other in accordance with the direction of excitation of said winding; at least one contact spring, having a free end, displaceable by said armature in accordance with the excitation of said winding, and a fixed end; at least one movable contact carried by said contact spring intermediate the ends of the latter and cooperable with a fixed contact; a portion of the permanent magnet flux force being stored in said contact spring during operation of said armature responsive to excitation of said winding, whereby the required excitation is inversely related to the resultant contact pressure; and an actuating member secured to an end of said armature; said contact spring having a forked free end defined by a pair of spaced spring tongues; said actuating member having an operator engaged between said spring tongues; said operator being adjustable relative to said spring tongues.

7. A polarized electromagnetic relay, as claimed in claim 2, wherein, with respect to a central plane through said relay and perpendicularly bisecting said armature at the pivot axis thereof, said relay is symmetrically constructed.

8. A polarized electromagnetic relay comprising, in combination, means including at least one permanent magnet, forming a permanent magnet structure providing a polarized permanent magnet flux path extending between a pair of opposite magnetic poles; a paramagnetic armature; means swingably mounting said armature between said poles; a magnetizing winding operatively associated with said armature, said armature swinging in one direction or the other in accordance with the direction of excitation of said winding; at least one contact spring, having a free end, displaceable by said armature in accordance with the excitation of said winding, and a fixed end; at least one movable contact carried by said contact spring intermediate the ends of the latter and cooperable with a fixed contact; a portion of the permanent magnet flux force being stored in said contact spring during operation of said armature responsive to excitation of said winding, whereby the required excitation is inversely related to the resultant contact pressure; and a flanged winding form supporting said winding; a pair of springs, each supported on a respective flange of said winding form and each electrically connected to a respective end of said winding; a base supporting said permanent magnet structure; and plural connectors on said base; each of said springs having a free end engaged with a responsive one of said connectors.

9. A polarized electromagnetic relay comprising, in combination, means including at least one permanent magnet, forming a permanent magnet structure between a pair of opposite magnetic poles; a paramagnetic armature; means swingably mounting said armature between said poles; a magnetizing winding operatively associated with said armature, said armature swinging in one direction or the other in accordance with the direction of excitation of said winding; at least one contact spring, having a free end, displaceable by said armature in accordance with the excitation of said winding, and a fixed end; at least one movable contact carried by said contact spring intermediate the ends of the latter and cooperable with a fixed contact; a portion of the permanent magnet flux force being stored in said contact spring during operation of said armature responsive to excitation of said winding, whereby the required excitation is inversely related to the resultant contact pressure; adjusting spring means operatively associated with said armature and deflected during operation of said armature responsive to excitation of said winding, a portion of the permanent magnet flux force being stored in said adjusting spring means to assist in the reduction of the required excitation with increasing contact pressure; said armature extending through said winding; a pair of bearing plates each extending along a respective one of a pair of opposite longitudinal sides of said armature and fixedly positioned in said permanent magnet structure; said armature being swingably mounted on a bearing pin extending between said plates at substantially the center of gravity of said armature; and a flanged winding form supporting said winding; said permanent magnet structure including a pair of pole pieces each having one of said magnetic poles; a two-part frame for said relay; said pole pieces being connected with the two parts of said relay frame; said bearing plates being fixedly supported in said pole pieces and the flanges of said winding form having projections engaged between said pole pieces and fixedly locating said winding form relative to said pole pieces.

10. A polarized electromagnetic relay, as claimed in claim 2, including a contact actuating member secured to an end of said armature; said adjusting spring means comprising an adjusting spring supported on said actuating member.

11. A polarized electromagnetic relay comprising, in combination, means including at least one permanent magnet, forming a permanent magnet structure providing a polarized permanent magnet flux path extending between a pair of opposite magnetic poles; a paramagnetic armature; means swingably mounting said armature between said poles; a magnetizing winding operatively associated with said armature, said armature swinging in one direction or the other in accordance with the direction of excitation of said winding; at least one contact spring, having a free end, displaceable by said armature in accordance with the excitation of said winding,

and a fixed end; at least one movable contact carried by said contact spring intermediate the ends of the latter and cooperable with a fixed contact; a portion of the permanent magnet flux force being stored in said contact spring during operation of said armature responsive to excitation of said winding, whereby the required excitation is inversely related to the resultant contact pressure; adjusting spring means operatively associated with said armature and deflected during operation of said armature responsive to excitation of said winding, a portion of the permanent magnet flux force being stored in said adjusting spring means to assist in the reduction of the required excitation with increasing contact pressure; and a contact actuating member secured to an end of said armature; said adjusting spring means comprising an adjusting spring supported on said actuating member; said actuating member extending through a groove in the end of said armature and being retained in said groove by portions of the armature bent over said actuating member.

12. A polarized electromagnetic relay, as claimed in claim 9, in which said frame halves have bendable flaps adjacent said adjusting spring means and bendable to adjust the initial tension of said adjusting spring means.

13. A polarized electromagnetic relay, as claimed in claim 1, in which said permanent magnet structure includes a pair of pole pieces each having a respective one of said magnetic poles; the cross sectional area of said pole pieces being such that said pole pieces are magnetically saturated by the permanent magnet.

14. A polarized electromagnetic relay comprising, in combination, means including at least one permanent magnet, forming a permanent magnet structure providing a polarized permanent magnet flux path extending between a pair of opposite magnetic poles; a paramagnetic armature; means swingably mounting said armature between said poles; a magnetizing winding operatively associated with said armature, said armature swinging in one direction or the other in accordance with the direction of excitation of said winding; at least one contact spring, having a free end, displaceable by said armature in accordance with the excitation of said winding, and a fixed end; at least one movable contact carried by said contact spring intermediate the ends of the latter and cooperable with a fixed contact; a portion of the permanent magnet flux force being stored in said contact spring during operation of said armature responsive to excitation of said winding, whereby the required excitation is inversely related to the resultant contact pressure; said contact spring comprising a two-ply leaf spring with the two plies formed to provide a fixed spring, with the two plies of the spring in juxtaposition except at the free end where the two plies of the spring diverge to form a pair of spaced tongues; a contact actuating member secured to an end of said armature and engaged between said tongues; means anchoring said contact spring at its fixed end; said movable contact being relatively elongated and secured adjacent one end of said contact spring; said movable contact extending outwardly from said spring at a shoulder and having a free end cooperable with said fixed contact; the distance from the anchoring point of said contact spring to the free end of said movable contact being greater than the distance from the anchoring point of said contact spring to the shoulder of said movable contact.

15. A polarized electromagnetic relay comprising, in combination, means including at least one permanent magnet, forming a permanent magnet structure providing a polarized permanent magnet flux path extending between a pair of opposite magnetic poles; a paramagnetic armature; means swingably mounting said armature between said poles; a magnetizing winding operatively associated with said armature, said armature swinging in one direction or the other in accordance with the direction of excitation of said winding; at least one contact spring, having a free end, displaceable by said armature in accordance with the excitation of said winding, and a fixed end; at least one movable contact carried by said contact spring intermediate the ends of the latter and cooperable with a fixed contact; a portion of the permanent magnet flux force being stored in said contact spring during operation of said armature responsive to excitation of said winding, whereby the required excitation is inversely related to the resultant contact pressure; said magnetic structure including a pair of pole pieces each having a respective one of said magnetic poles; at least one metal bridge member extending between said pole pieces adjacent an end of said armature and pivotal about one of said pole pieces, said bridge member having a portion engaged with said armature to restrain the same to a selected rest position and being displaceable about its pivotal mounting by said armature upon movement of the latter from its selected rest position responsive to excitation of said winding.

16. A polarized electromagnetic relay, as claimed in claim 15, including spring means constraining said bridge member into engagement with both pole pieces.

17. A polarized electromagnetic relay, as claimed in claim 15, in which said bridge member is formed of ferromagnetic material.

18. A polarized electromagnetic relay, as claimed in claim 16, in which said bridge member is formed from diamagnetic material.

19. A polarized electromagnetic relay, as claimed in claim 7, including contact operating members at each end of said armature; each contact operating member being effective to operate at least one of said contact springs; the contacts controlled by said contact springs including contacts normally closed in the center position of said armature and contacts normally opened in the center position of said armature and said contact springs and said contacts being so related that, depending upon the direction of excitation of said winding, certain contacts are operated and certain other contacts remain unoperated.

20. A polarized electromagnetic relay, as claimed in claim 19, in which said contacts include a plurality of change-over contacts.

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