

June 26, 1962

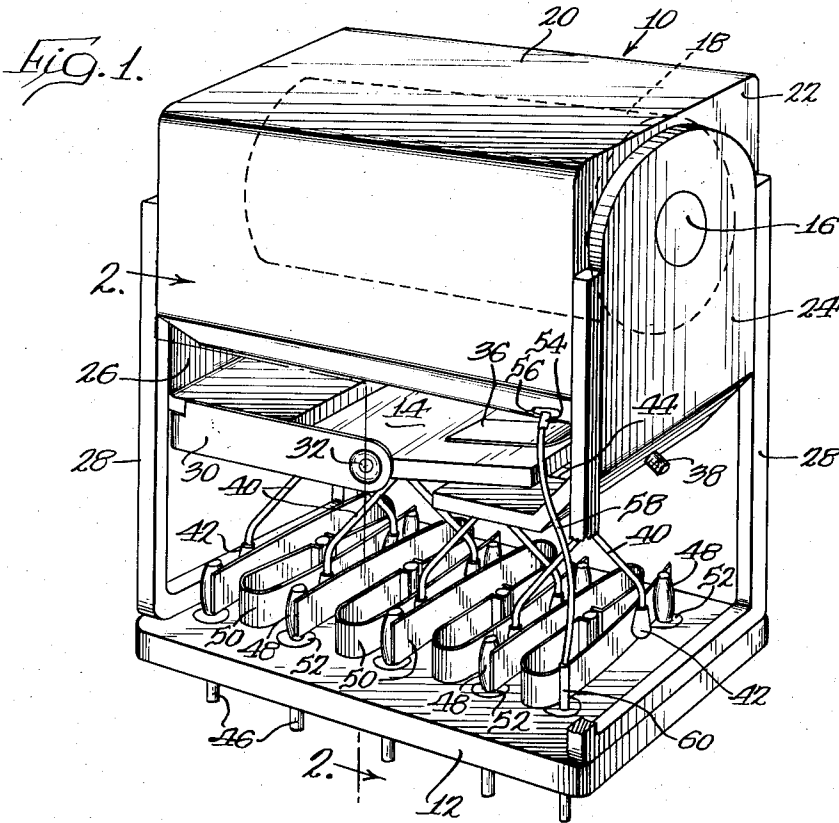
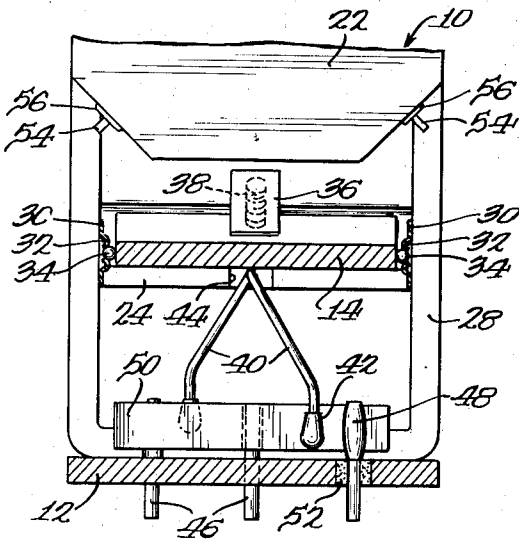
L. J. GRESHEL

3,041,422

RELAY

Filed Sept. 9, 1959

2 Sheets-Sheet 1



INVENTOR,  
*Leonard J. Greshel*  
 BY *Brown Jackson, Beckler & Demmer*

*Attys.*

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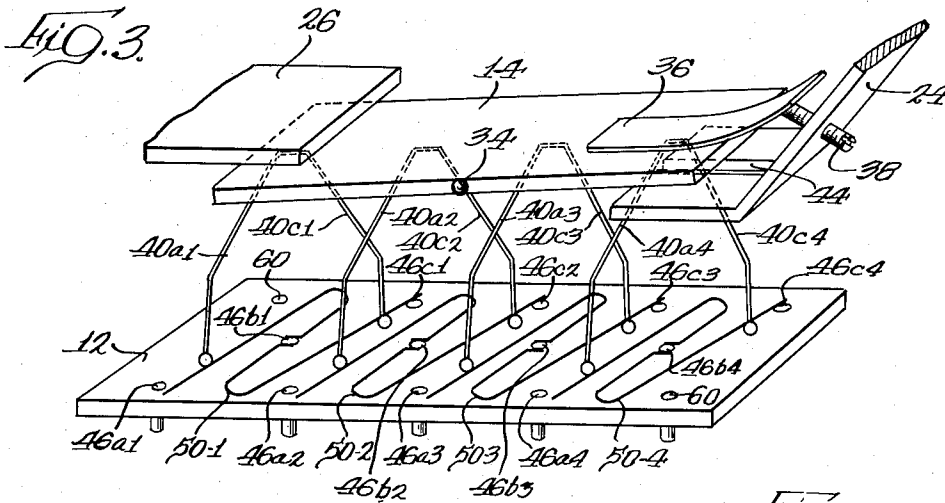
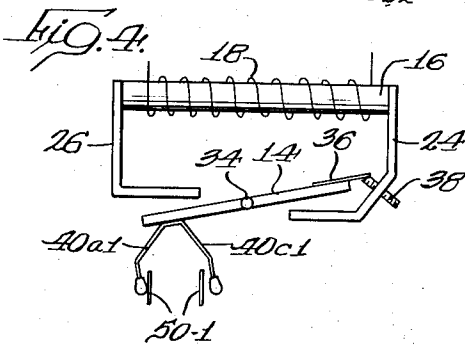
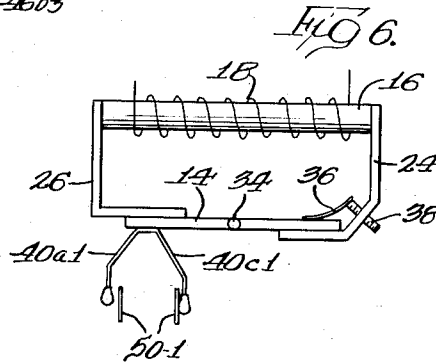
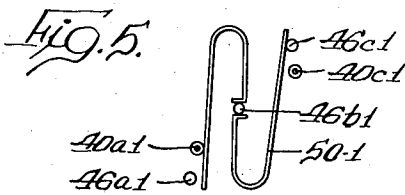
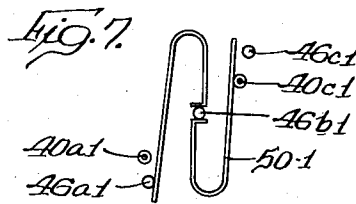
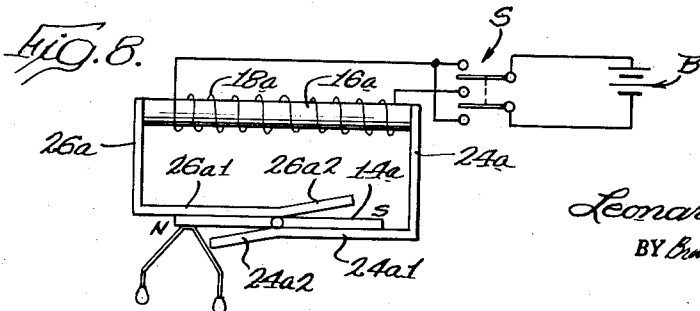
L. J. GRESHEL

3,041,422

RELAY

Filed Sept. 9, 1959

2 Sheets-Sheet 2



INVENTOR.  
*Leonard J. Greshel*  
 BY *Brown Jackson Smith & Associates*

*Attys.*

1

3,041,422  
RELAY

Leonard J. Greshel, Cohasset, Mass., assignor to North Electric Company, Galion, Ohio, a corporation of Ohio  
Filed Sept. 9, 1959, Ser. No. 839,009  
7 Claims. (Cl. 200-104)

The present invention relates to relays, and particularly, to improvements in the construction of relays which may in operation be subjected to severe accelerative and decelerative forces, which are required to operate in accordance with exacting specifications throughout a prolonged service life under exceedingly adverse conditions, and which are required to be of the smallest possible size for a given capacity.

The object of the invention, stated more in detail, is to provide an improved construction for relays, which construction facilitates manufacture of relays to exacting specifications by mass production methods, accommodates decrease in the size of relays of a given capacity, affords particular sensitivity, mitigates improper operation of the relay when subjected to rectilinear and/or curvilinear acceleration or deceleration—even translational accelerative forces in the order of 50-75 gravities in any direction, renders the relay capable of withstanding vibrational forces of 15-20 gravities at from 10 to 2,000 cycles per second without mechanical damage and without adversely affecting operating characteristics, accommodates operation of the relay over a temperature range of from minus 65 degrees C. to plus 125 degrees C., renders the contacts of the relay essentially bounce-free, maintains accurately controlled pull-in and drop-out values irrespective of the conditions to which the relay is subjected, mitigates contamination and excessive wear of the contacts to increase contact life, facilitates hermetic sealing of the relay, and otherwise satisfies existing specifications applying to relays.

More particularly, it is one object of the present invention to provide an improved relay construction comprising a new combination of relay components facilitating production of an extremely sturdy and compact relay capable of satisfying the most rigid specifications.

Another object of the invention is to provide an improved relay construction embodying an oscillatory armature operated by a single coil, the armature withstanding vibratory, accelerative and decelerative forces of high order and the coil accommodating maximum utilization of available space while at the same time providing an efficient flux path.

An additional object of the invention is to provide an improved relay construction comprising a compact stacked arrangement of a coil, an armature and a terminal and contact assembly wherein the armature is sandwiched between the coil and the contact assembly.

A further object of the invention is the provision of an improved relay construction embodying the above defined stacked arrangement of components wherein the components themselves constitute a rigid frame for the relay and provide for a fixed pivot axis for accurately supporting the armature.

Specifically, it is an object of the invention to provide an improved relay structure comprising a coil having a rigid core protruding from the ends thereof, a rigid pole piece fixed to each end of the core, a rigid terminal header fixedly supported by said pole pieces in spaced parallel relation to said core and together with said pole pieces and said core defining a rigid frame, and an armature pivotally mounted on said frame in the space between said coil and said header, said pole pieces extending from said core toward said header and extending the space between said header and said coil, the pole pieces in-

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cluding end portions extending to opposite sides of the armature for cooperation therewith.

Yet another object of the invention is to provide an improved relay structure as above defined wherein terminals are projected through said header, the stationary and movable contacts of the relay are constituted by and/or are directly mounted on the terminals at the side of said header adjacent said armature, and the armature directly actuates the movable contacts on said header whereby no leads are required from the terminals to the contacts.

A further object of the invention is the provision of an improved relay structure as described in the preceding paragraphs including non-contaminant means sealingly enclosing the coil, non-contaminant leads from the coil to the terminal header, and non-contaminant enclosure means for the space between said header and said coil for sealing the armature and the contacts in a contaminant-free atmosphere, thereby to insure proper operation of the armature and to improve contact life. It is particularly the object hereof to eliminate the presence of organic materials, such as customary insulators, in the vicinity of the contacts, the armature and the armature bearings.

A still further object of the invention is the provision of an improved terminal and contact assembly for relays, including terminals directly carrying and/or constituting the contact means, and movable contact springs permissively engageable with their respective stationary contacts for minimizing contact-bounce and chatter.

In addition to the foregoing, it is an object of this invention to provide improved relay structures as aforesaid including a first embodiment having a normally released spring biased armature and a second embodiment comprising a latching relay.

Other objects and advantages of the invention will become apparent in the following detailed description.

Now, in order to acquaint those skilled in the art with the manner of making and using my improved relay structure, I shall describe, in connection with the accompanying drawings, preferred embodiments of the relay and preferred manner of making and using the same.

In the drawings, wherein like reference numerals indicate like parts:

FIGURE 1 is a perspective view of a first embodiment of the relay structure of the invention, the view showing the relay with its outer hermetic sealing can removed;

FIGURE 2 is a fragmentary vertical section taken substantially on line 2-2 of FIGURE 1;

FIGURE 3 is a fragmentary perspective representation of the pole pieces, armature and contact assembly of my improved relay, the view schematically depicting the contacts and the cooperation therewith of the armature carried actuators;

FIGURE 4 is a schematic elevational representation of the coil, pole pieces, armature, one actuator pair and one contact set of the relay of the invention, the view illustrating these components in their normal positions;

FIGURE 5 is a schematic plan view of the one actuator pair and one contact set depicted in FIGURE 4;

FIGURES 6 and 7 are views similar, respectively, to FIGURES 4 and 5, but showing the armature, the actuator pair and the contact set in operated position; and

FIGURE 8 is a view similar to FIGURES 4 and 6 illustrating the latching relay embodiment of this invention.

Referring now to the drawings, and particularly to FIGURES 1 and 2, I have shown my improved relay construction as comprised of a stacked arrangement of a coil assembly 10, a terminal header 12 paralleling the axis of the coil assembly in spaced relation thereto, and an

armature 14 sandwiched between the header and the coil assembly.

The coil assembly 10 includes a rigid axial core 16, a coil 18 wound on the core, and a coil-enclosing can 20 through the ends 22 of which the core protrudes. Preferably, the ends 22 of the can 20 are fixedly secured to the core 16 adjacent the ends of the core to constitute the heads of a coil receiving spool. The spool thus defined may carry conventional insulating washers and tape, or may be insulated by a coating of Teflon or sprayed glass. The coil 18 is wound directly on the core for maximum utilization of winding space, or in other words, to maintain at a minimum the external dimensions of the coil. The components of the can 20 are hermetically sealed to one another and the core 16 thereby sealingly to enclose the coil 18.

To each of the protruding ends of the core 16 is fixedly secured a rigid pole piece 24 and 26, respectively. The pole pieces are preferably fixed to the ends of the core by peening protruding portions of the core into countersunk holes in the two pole pieces, each pole piece and the core having smooth mating faces and the assembly being held under pressure during peening, thereby to afford a structure that essentially is both the physical and magnetic equivalent of a one-piece structure. Preferably, the magnet material used is a nickel-iron alloy, which has a low coercive force and a high permeability and appears completely immune to aging effects when used at temperatures up to 125 degrees C. The pole pieces 24 and 26 extend radially in the same direction from the core 16, and radially outward of the can 20 are extended toward one another in respective planes that are parallel to and spaced from one another and the adjacent wall of the can 20 and the axis of the core 16.

The terminal header 12 is a rectangular planar member of a length equal substantially to the core 16 and of a width not significantly greater than the coil enclosing can 20. This member is preferably formed of metal having relatively low permeability, and it is rigidly joined to the pole pieces by means having negligible permeability. In the disclosed embodiment, the header is secured to the pole pieces 24 and 26 by U-shaped supports 28 which are preferably formed of stainless steel, the legs of each U being secured, as by welding, to the opposite sides of the respective pole piece 24, 26 and the bight portion thereof constituting the mounting surface for the header, to which the header is fixed as by welding, whereby the header is disposed in spaced parallel relation to the coil assembly at the same side thereof as the ends of the pole pieces.

As thus assembled, the core 16, the pole pieces 24 and 26 and the header 12 (together with the supports 28) comprise a rigid box-like frame for the relay, which frame has the necessary mechanical strength to endure the high shock and vibration environment to be encountered by the relay, and the strains to be imposed thereon by virtue of the wide variation in temperature to which the relay is exposed. Consequently, this rigid frame is well adapted for definition of a fixed pivot axis for the armature 14. The armature is mounted on the said frame by means of a U-shaped bracket 30 which is rigidly secured to the frame, preferably by welding the legs of the same to the left-hand pole piece 26 at the location where the pole piece turns into the space between the coil assembly and the header. The legs of the bracket 30 extend inwardly to opposite sides of the pole piece 26, within the confines of the box-like frame, and at the inner ends thereof include bearing portions 32 defining a pivot axis for the armature. The said axis extends in spaced parallel relation to the header 12 transversely of the axis of the coil and its core at a point centrally intermediate the planes of the end portions of the pole pieces 24 and 26. The bearings 32 are preferably formed by a forward and reverse drawing operation whereby each includes an inwardly extending bulbous portion having a cylindrical center or core portion.

The armature 14 comprises a substantially rectangular planar member pivotally mounted on its transverse axis on the bracket 30 and having its longitudinal axis extending in the same direction as the core 16 and the header 12. At the opposite sides thereof, and coincident with its transverse axis, the armature carries a pair of balls 34 comprising the bearings thereof. Preferably, the balls are formed of stainless steel to close tolerance and are welded to the armature.

The bearing balls 34 of the armature are journaled in the cylindrical core portions of the journal bearings 32 to have substantially a circular line of bearing contact therewith. Bearing play is held within extremely close limits of from about .0002 inch to about .0005 inch to mitigate armature vibration and maintain relay adjustments under all conditions. Also, the reverse draw of the journal bearings 32 afford a curved smooth surface to minimize frictional resistance to movement when the side edges of the armature engage the armature mounting bracket.

The armature 14 is formed of metal having high permeability, and the resulting magnetic circuit compares in sensitivity with much larger double-coil relay structures. The armature mounting bracket 30 is preferably formed of beryllium copper because of the formability, hardenability and non-magnetic properties of this metal. After formation, the bracket is age-hardened for minimum wear and maximum vibration resistance. This journal, in combination with the stainless steel ball bearings, affords an exceedingly accurate pivot for the armature, and one that will have exceptionally long service life.

The armature thus extends generally in the same direction as the header 12 and core 16 and is sandwiched between the two with its left end extending below the end portion of the pole piece 26 and its right end extending above the end portion of the pole piece 24, whereby the armature is adapted to be attracted by the pole pieces upon energization of the coil 18. In its operated position, the armature is substantially parallel to the ends of the pole pieces. Residuals (not shown) may comprise non-magnetic plates or platings on the opposed surfaces of the armature and/or the pole pieces, or may comprise adjustable residual screws. To return the armature from its operated position, a return spring 36 in the form of a flat strip of beryllium copper or the like is fixed at one end to the upper surface of the right-hand end portion of the armature, the free end of the spring reacting against an abutment 38. Preferably, the abutment is adjustable to accommodate adjustment of the relay characteristics. To this end, the right-hand pole piece 24 includes an angular portion intermediate the portions thereof extending radially of and parallel to the core 16, the angle of the intermediate portion suitably being 45 degrees. Threaded through this angular portion of the pole piece is a screw, preferably formed of stainless steel, which constitutes the said abutment 38. To limit movement of the armature away from the pole pieces under the urge of the spring 36, suitable back-stop means (not shown) are provided for the armature, the said means also preferably being adjustable.

Secured to and projecting downwardly from the armature, i.e., toward the header 12, are a plurality of actuators 40 which will serve to actuate the movable ones of contact means carried by the header. In the illustrated embodiment of the invention, there are four contact sets each having a pair of movable contact means. Consequently, the armature carries eight actuators each comprising a stainless steel wire having a glass bead 42 at its lower end for engagement with the respective movable contact. As will be appreciated, the armature may carry more or less actuators as may be required for any particular contact assembly, the assemblies contemplated, however, requiring an even number of actuators. For any such assembly, the actuators are of even numbers to opposite sides of the armature pivot axis and corresponding actuators to opposite sides of said axis are spaced equal

distances from that axis to maintain the balanced condition of the armature. To accommodate the actuators at the right end of the armature, the end portion of the right-hand pole piece 24 is slotted longitudinally thereof, as is indicated at 44.

According to the present invention, the terminal header 12 is provided with a plurality of terminals projecting therethrough which terminals, at the side of the header 12 adjacent the armature, directly carry and/or constitute the contact means of the contact assembly embodied in the relay, whereby the movable contacts are disposed to be conveniently actuated by the armature, the relay assembly is decreased in size and no leads are required between the terminals and the contacts. For the sake of clarity in FIGURES 1 and 2, I have indicated the contact mounting terminals at 46, the stationary contacts at 48 and the movable contacts at 50, thereby to avoid obliteration by lead lines and numerals of the structural make-up of the contact assembly. The specific arrangement of the disclosed contact assembly will be described in detail hereinafter in connection with FIGURES 3 to 7. For the present, suffice it to say that there are three parallel rows of terminals 46, the center row of which carries the movable contacts 50 and the outboard rows of which carry the stationary contacts 48, the several contacts being mounted on the terminals to the side of the header adjacent the armature.

As previously stated, the header plate 12 is preferably formed of metal. This plate is provided with holes therethrough for reception of the terminals 46, which are in the form of rigid pins extended perpendicularly through the plate and insulatedly sealed thereto by glass compression seals 52. Each stationary contact 48 comprises a barrel-shaped member formed of precious metal and telescoped onto and soldered or otherwise secured to the respective pin 46. The movable contacts 50 are each fabricated of a pair of generally U-shaped springs secured at the ends of respective legs thereof to the opposite sides of a respective pin 46 in the center row, whereby each contact 50 is of S-shape and has its terminal pin disposed centrally thereof. By virtue of this construction, each end of each spring 50 is disposed to engage a respective stationary contact 48. The S-shaped springs 50 are each pre-stressed so that the ends thereof are normally biased toward pressure engagement with their respective stationary contacts 48 thereby to afford a permissive-make contact arrangement. The springs are each preferably made of a hardenable alloy, specifically a silver-magnesium-nickel alloy having about 99.5% silver which is oxidation hardened with good spring properties. This material is very ductile in the soft state and can be formed into intricate shapes, and then irreversibly hardened by oxidation. In the hardened state, it is an excellent spring and contact material with an electrical conductivity of 70-80% of copper, in the temperature range stated. Above 400 degrees F., its conductivity is better than that of copper. Heat conductivity is proportionally as good and the material provides an excellent heat sink for heavy current arcing and power losses. The stationary contacts 48 are preferably a silver alloy with compatible properties.

The movable contact springs 50 are actuated by the actuators 40, the glass beads 42 of which afford insulated engagement between the actuators and the contacts. Each spring 50 requires two actuators, and the actuators are thus provided in pairs, one pair for each spring. The actuators of each pair are disposed respectively adjacent the free ends of the spring to the side of the respective end facing toward the respective stationary contact 48, whereby the actuator is adapted to move the contact 50 away from the contact 48 and to permit the contact 50 to move into engagement with the contact 48 upon appropriate movement of the armature 14. The actuators of each pair, due to the disposition of the respective spring 50, define a plane perpendicular to the plane of the armature and inclined relative to the axes of the armature, and

each pair of actuators may suitably be secured to the armature as a unit at this approximate inclination in assembly of the armature and actuators. After assembly, the stainless steel wires forming the actuators may readily be bent to effect adjustment of the contacts and the operating characteristics of the relay.

In particular, the actuator wires may be so adjusted as to provide either a make-before-break or a break-before-make characteristic as desired. In either case, however, the respective glass beads 42 are separated from the closed contacts in the end positions of armature movement, thereby to insure a permissive-make contact arrangement as previously described. In particular, each actuator wire 40 is so adjusted as to provide between the glass bead and its associated movable contact, in the contact closed position, a gap of from .002 inch to .004 inch. Each spring is thus closed under its own tension, and the arrangement thus allows for some armature bounce on operation and release and for some armature motion during shock and vibration without affecting the closed contacts. This minimizes contact bounce and chatter during vibration. It also eliminates variation in contact pressure as the contact spring is at a very low stress level and only changes contact pressure about 1/2 to 1 gram for each .001 inch of contact movement. This means that a loss of .005 inch of contact material during use of the relay will result in a decrease in contact pressure of only 2 1/2 to 5 grams. The structure thus insures constant contact pressure, which in turn insures constant resistance and a linear rate of wear on the contacts during the life of the relay.

Contact life on the relay of the present invention is further increased by complete elimination of organic materials from the vicinity of the contacts. In particular, I construct my relay as to facilitate enclosure of the contacts in a contaminant-free atmosphere. As a first step in this direction, I have enclosed the coil 18 in its own hermetically sealed can 20. To supply current to the coil, the coil ends are secured to terminal pins 54 which extend through the can 20 in insulatedly sealed relation thereto, the pins preferably being glass-sealed, as at 56, in the same manner as the terminals 46. The terminal pins 54, in the preferred embodiment of the invention, extend from diagonally opposite lower corner portions of the can 20 and are connected, by means of non-contaminant leads 58, to respective adjacent ones of a pair of current supply terminals 60 which are mounted in diagonally opposite corner portions of the header 12. The terminals 60 are mounted in the same manner as the pins 46, and are each preferably aligned with the pins 46 in the respective outboard row of pins thereby to afford a compact, unitary terminal assembly for the relay. The leads 58 may be insulated by a coating of glass, or may be left uninsulated, so long as there is no organic or contaminant material involved. As the final step, I hermetically seal the entire relay assembly within a second can (not shown) which fits down over the can 20, the pole pieces 24 and 26, the supports 28 and the edge of the header 12, and is hermetically sealed about the edge of the header. This can, which is of a standard known construction not requiring special illustration, and the can 20 are both preferably formed of tinned brass. In the resultant structure, the space between the coil assembly 10 and the header 12 is closed and hermetically sealed. The only materials within this space are metal and glass, which are non-contaminants. The only relatively moving parts are stainless steel on hardened beryllium copper and glass on the hardened alloy of the contact springs. Thus, there is nothing within the sealed space that could contaminate the contacts, interfere with their operation, or hasten their wear. Moreover, the armature bearings are thus also sealed within a contaminant-free atmosphere thereby to insure long service life for the bearings and the contacts.

In view of the foregoing, it is to be appreciated that the present invention provides a strong, rigid relay construc-

tion that is exceptionally compact, that facilitates manufacture of relays in small sizes and to exacting specifications, that facilitates accurate production of small relays by mass production methods and that assures long, efficient service life for the relay due not only to the constructional features involved but the enclosure of all operational components in a contaminant-free atmosphere. In addition, the structure facilitates embodiment of complex switching arrangements in minimum space.

As a specific example of the physical capabilities of my improved relay structure, I have embodied the same within an exterior enclosure can  $1\frac{1}{4}$  inches high,  $1\frac{1}{8}$  inches long, and  $\frac{5}{8}$  of an inch wide. The weight of the relay is only .13 pound. An exemplary coil embodies 9500 turns of #42 wire having a resistance of 1750 ohms, operate current of 14.1 milliamps, operate voltage at 24.8 volts, 135 operates ampere turns, and power of 350 milliwatts. Dielectric strength is 1000 v. R.M.S. at sea level, all terminals to ground, and terminal to terminal. The relay withstands vibration in the order of 15-20 gravities at 10 to 2000 cycles per second and shock in the order of 50-75 gravities of 11 millisecond duration. It operates over a temperature range of minus 65 degrees C. to plus 125 degrees C. Maximum contact resistance is .02 ohm at 25 degrees C. and rated current.

Relative to the contact assembly, reference is made to FIGURES 3 to 7 wherein I have schematically depicted a four-pole double-throw switching arrangement embodied in the relay. As shown in FIGURE 3, the terminals 46 are disposed in three parallel rows, the terminals of which are indicated as 46a, 46b, and 46c, respectively, each row including four terminals 46a-1, 46a-2, 46a-3 and 46a-4, 46b-1, 46b-2, etc. There are four switching sets in all, each including a movable contact spring 50-1, 50-2, 50-3 and 50-4, respectively, and a terminal 46b-1, 46b-2, etc. for the movable contact; and a pair of stationary contact terminals or contact means 46a-1 and 46c-1, 46a-2 and 46c-2, etc., with which the associated movable contact cooperates. The movable contacts are pre-stressed so that the free ends of each are normally engageable with the respective stationary contacts, i.e., so that contact spring 50-1, (connected to terminal 46b-1) for example, normally tends to engage the stationary contact means 46a-1 and 46c-1. To operate the contact springs, each pole of the assembly includes a pair of actuators 40a-1 and 40c-1, 40a-2 and 40c-2, etc., each of which is disposed to engage adjacent the respective free end of the respective spring 50-1, 50-2, etc. Referring to FIGURES 4 and 5, when the relay coil is de-energized, the spring 36 biases the armature 14 away from the pole pieces to turn the armature in a counter-clockwise direction, whereupon the right-hand actuator 40c-1, etc., of the respective pair moves to the right to permit the right-hand end of the respective spring 50-1, etc., to engage the respective stationary contact 40c-1, etc., and to force the left-hand end of the respective spring 50-1, etc., away from its respective stationary contact 46a-1, etc.

Upon energization of the relay coil 18, as depicted in FIGURES 6 and 7, the armature 14 is attracted to the pole pieces 24 and 26 and thereby rotated in the clockwise direction causing the actuator 40a-1, etc., to move in the direction away from the left end of the spring 50-1, etc. to permit the left end of the respective spring to engage the respective stationary contact means 46a-1, etc., and also causing the actuator 40c-1, etc. to engage the right end of the spring 50-1, etc., and separate the same from its respective stationary contact means 46c-1, etc. Thus, the contacts are all made permissively with the advantages above noted and a four-pole double-throw switching means having the said advantages is provided within a rectangular space  $1\frac{1}{8}$  inches long and  $\frac{5}{8}$  of an inch wide in the described physical embodiment of the relay.

In addition to the foregoing, the compact switching ar-

range described affords the advantages that the circuits at each of the stationary contact terminals 46a and 46c may be made either before or after the circuits are made or broken at the other of the stationary contact terminals. In other words, the circuits at the terminals 46c may be made either before or after the circuits at the terminals 46a are broken, and the circuits at the terminals 46a may be made either before or after the circuits at the terminals 46c are broken. Moreover, the circuits at some of the stationary contact terminals 46c may have a make-before-break characteristic, while the circuits at the other of the terminals 46c may have a break-before-make characteristic, and likewise with the circuits at the terminals 46a. This particular advantage is afforded by virtue of movement of the armature a predetermined distance between definite limits, movement of all the contact actuators 40 an equal distance in the direction parallel to the header, and the individual adjustability of the actuators.

As to adjustment, the back stop means (not shown herein) for the armature is first adjusted to provide proper armature travel. Then, the actuators 40 are adjusted with the armature first clamped against the pole pieces and then clamped against the back stop means. Finally, the return spring screw 38 is adjusted to provide the proper operate and release points current-wise for the coil. After adjustment, the screw 38 is locked in position, such as by solder.

The above described embodiment of the invention is a normally released relay operated only upon and during energization of the coil 18. In addition to this embodiment, the present invention provides a latching relay affording all of the advantages of the described relay construction and having the further advantage that it is operated on opposite hands by momentary current pulses of reversed polarity and is retained in the condition to which it was last operated. Constructionally, the latching relay is similar to the relay above described except for the few differences depicted schematically in FIGURE 8. In particular, as shown, the pole pieces 24a and 26a in the latching relay are extended inwardly in a direction generally parallel to the core 16a to a position adjacent the transverse or pivot axis of the armature 14a and are then inclined diagonally away from the armature. In other words, the terminal part of each pole piece includes an inner portion 24a-1, 26a-1 and an outer portion 24a-2, 26a-2 which portions are relatively inclined and define an obtuse angle therebetween. The degree of angularity between the two portions is generally the difference between 180 degrees and the maximum swing that the armature is to be permitted. Preferably, the two pole pieces have the same angularity and both extend inwardly to locate the juncture between said two portions thereof adjacent the pivot axis of the armature, the portions 24a-1 and 26a-1 and the portions 24a-2 and 26a-2 being parallel and disposed to opposite sides of the armature and its pivot axis.

The armature 14a is a permanent magnet, having high coercive force. The opposite ends of the armature comprise the poles of the magnet, as illustrated by the pole indications in FIGURE 8. Assuming the left-hand end of the armature is the north pole and the right-hand end of the armature is the south pole, and that the armature is in the position shown, the relay is operated by supplying current to the coil 18a in a direction to cause the pole piece 24a to be the south pole and the pole piece 26a to be the north pole of the coil. Thereupon, the north polarity of the portion 26a-1 of the pole piece 26a repels the north pole of the armature while the south polarity of the portion 24a-2 of the pole piece 24a attracts the north pole of the armature, and the south polarity of the portion 24a-1 of the pole piece 24a repels the south pole of the armature while the north polarity of the portion 26a-2 of the pole piece 26a attracts the south pole of the armature. Thus, four forces are at work simultaneously,

two repelling and two attracting, to insure positive and rapid operation of the armature by virtue simply of momentary energization of the coil 18a. To return the armature to its original position, the coil is energized on the opposite hand, whereupon four forces are again at work to effect prompt operation of the armature. Once moved, the armature will remain in the position to which it was last moved by virtue of its own magnetic properties.

To effect operation of the relay in the manner described, a number of control circuits can be employed. For example, the coil may be energized from the same source, or from sources of equal power, on both hands, in which case the armature does not require a return spring. Simply by way of example, the coil 18a of the relay could suitably be energized from a battery B via a switch S capable of reversing the flow of current from the terminals of the battery thereby to control the polarity of the field produced by the coil. On the other hand, the control circuit might be so devised as to utilize a relatively high power source for operating the armature in the clockwise direction and a relatively low power source for operating the armature in the counter-clockwise direction, in which case a return spring could well be employed to assist the lower powered source in performance of its function.

It should be understood, of course, that the angles of the pole pieces as illustrated in FIGURE 8 have been exaggerated for purposes of convenience and clarity of disclosure. Those skilled in the art may readily determine the appropriate angles from the foregoing description and upon consideration of the degree of armature travel desired.

From the foregoing, it is to be appreciated that the present invention provides an exceedingly compact relay of rigid construction that is well adapted to withstand the translational and vibratory forces referred to hereinbefore, that is adapted to operate precisely and efficiently over a long service life even in the adverse environmental conditions described, that provides a contaminant-free atmosphere within which all operating components of the relay are enclosed, and that further accommodates complex switching arrangements in a compact structure. It is thus apparent that the objects and advantages of the invention have been shown herein to be attained in a convenient economical and practical manner.

While I have shown and described what I regard to be the preferred embodiments of my invention, it will be appreciated that various changes, rearrangements and modifications may be made therein without departing from the scope of the invention, as defined by the appended claims.

I claim:

1. In a relay structure, a coil core, a pole piece fixed to each end of said core, a header, support means fixed to said header and said pole pieces to support said header in spaced parallel relation to said core and together with said header, said pole pieces and said core comprising a rigid frame, said pole pieces extending from said core toward said header and at a location spaced from said core extending into the space between said header and said core, an armature carried by said rigid frame in the space between said header and said core for cooperation with said pole pieces mounted for arcuate rotation about its transverse axis, a plurality of stationary contacts on the side of said header adjacent said armature, a plurality of movable spring contacts mounted with the longitudinal axis thereof extending transversely of said armature and on said side of said header, said movable spring contacts being cooperable with said stationary contacts and due to the spring force thereof normally being engageable with respective ones of said stationary contacts, and actuators extending from and arcuately operable with said armature mounted to apply the horizontal component of said arcuate travel to said movable contacts for moving said contacts laterally in a plane parallel to said header and out of engagement with

their respective stationary contacts and for permitting engagement of said movable contacts with their respective stationary contacts upon movement of said armature.

2. In a relay structure, a coil core, a pole piece fixed to each end of said core, a header, support means fixed to said header and said pole pieces to support said header in spaced parallel relation to said core and together with said header, said pole pieces and said core comprising a rigid frame, said pole pieces extending from said core toward said header and at a location spaced from said core extending into the space between said header and said core, an elongate armature pivotally mounted on its transverse axis on said frame in the space between said header and said core with its longitudinal axis extending in the same direction as said core, said pole pieces being angularly disposed to extend toward each other in respectively parallel planes, between said core and said armature and between said armature and said header, three parallel rows of terminals extending through said header, the terminals in the outboard rows to the side of said header adjacent said armature comprising stationary contact means, movable contacts mounted on the terminals in the middle row to the side of said header adjacent said armature and each comprising spring means of S-shape connected centrally thereof to the respective terminal, the free end portions of each movable contact due to the spring force thereof normally being engageable with respective ones of said stationary contact means, and pairs of actuators extending from said armature to respective ones of said movable contacts, the actuators of each pair being engageable with respective end portions of the respective movable contacts for moving the respective end portions out of engagement with the respective stationary contact means and for permitting engagement of the respective end portions with the respective stationary contact means.

3. In a relay, a terminal and contact assembly comprising a header, three parallel rows of terminals extending through said header, the terminals in the outboard rows comprising stationary contact means, movable contacts mounted on the terminals in the middle row and each comprising spring means of S-shape connected centrally thereof to the respective terminal, the free end portions of each movable contact due to their own resiliency normally being engageable with respective ones of said stationary contact means, and means for moving said movable contacts into and out of engagement with their respective stationary contact means.

4. In a relay, a terminal and contact assembly comprising a header, three parallel rows of terminals extending through said header, the terminals in the outboard rows to one side of said header comprising stationary contact means, movable contacts mounted on the terminals in the middle row to said one side of said header and each comprising spring means of S-shape connected centrally thereof to the respective terminal, the free end portions of each movable contact due to the spring force thereof normally being engageable with respective ones of said stationary contact means, a pivotally movable armature spaced from said one side of said header, and pairs of actuators extending from and arcuately movable with said armature to move respective ones of said movable contacts laterally in a plane which extends substantially parallel to said header, the actuators of each pair being engageable with respective end portions of the respective movable contact for moving the respective end portion out of engagement with the respective stationary contact means.

5. In a relay structure, a coil having a core, a pole piece fixed to each end of said core, said pole pieces including portions extending outwardly in the same direction from said core and portions extending toward one another outwardly of one side of said coil, said pole pieces and said coil comprising frame means, an elongate armature pivotally mounted on its transverse axis on said frame means at said one side of said coil, the longi-

tudinal axis of said armature extending generally in the same direction as said core, the portions of said pole pieces extending toward one another extending generally in the same direction as said core and said armature to opposite sides of said armature, the last-named portions of said pole pieces extending in said direction to substantially the location of the transverse axis of said armature and then extending diagonally away from said armature, said armature comprising a permanent magnet having its magnetic poles at the opposite ends thereof, and means for at least momentarily energizing said coil and for controlling the polarity of its field upon each energization thereof.

6. In a relay structure, a coil having a core, a pole piece fixed to each end of said core, a header, support means fixed to said pole pieces and said header to support said header in spaced parallel relation to said core and together with said header, said pole pieces and said core comprising a rigid frame, said pole pieces extending outwardly from said core toward said header and extending into the space between said header and said coil, an elongate armature pivotally mounted on its transverse axis on said frame in the space between said header and said coil, said pole pieces being disposed respectively to opposite sides of said armature, said pole pieces each including relatively inclined portions defining an obtuse angle therebetween, the juncture of the said portions of each pole piece being located adjacent the transverse axis of said armature at the respective side thereof, the portion of each pole piece to one side of the said juncture thereof being generally parallel to the portion of the other pole piece to the other side of its said juncture, said armature comprising a permanent magnet having its magnetic poles at the opposite ends thereof, and means for at least momentarily energizing said coil and for con-

trolling the polarity of its field upon each energization thereof.

7. In a relay structure comprising a coil assembly including a core and pole pieces fixed to said core, an armature mounted for pivotal operation about its transverse axis responsive to energization of said coil and said pole pieces, support means fixed to said coil assembly, a plurality of stationary contacts carried by said support means adjacent said armature, a plurality of movable spring contacts mounted on said support means with the longitudinal axis thereof extending transversely of said armature for cooperation with said stationary contacts, said movable contacts due to the spring force thereof normally being engageable with the respective ones of said stationary contacts, and actuators extending from said arcuately operable armature mounted for movement therewith to move the movable contacts laterally out of engagement with their respective stationary contacts.

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