Jan. 24, 1956 W. D. BUCKINGHAM 2,732,454

POLAR RELAY

Filed May 1, 1953

FIG. 1

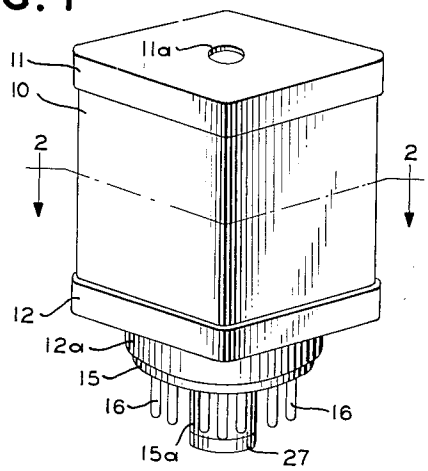


FIG. 2

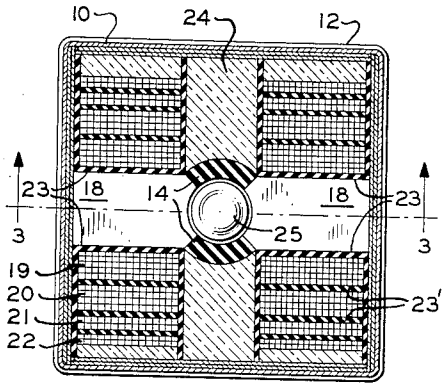


FIG. 4

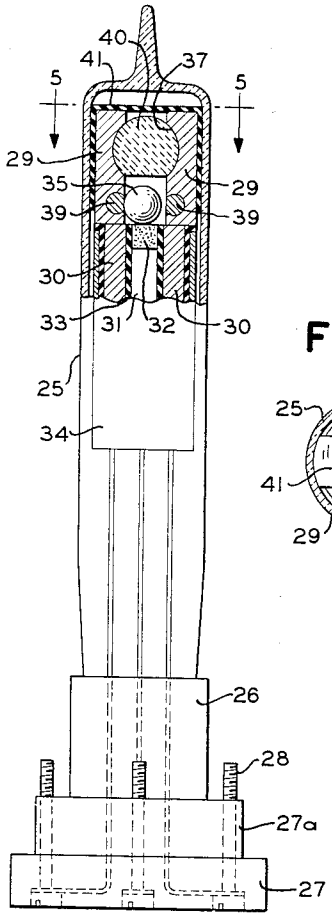


FIG. 5

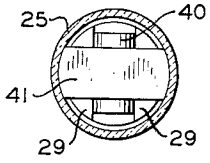
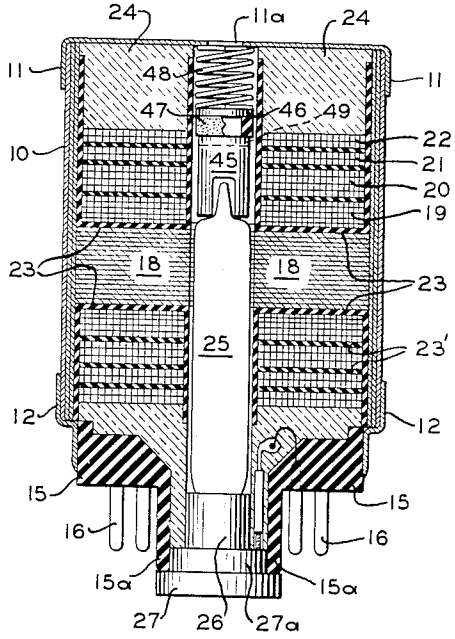


FIG. 3



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2,732,454

POLAR RELAY

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Application May 1, 1953, Serial No. 352,355

12 Claims. (Cl. 200—87)

My invention relates to a high-speed vacuum relay in which the armature is a ball or equivalent member composed of magnetizable material disposed in an electromagnetic field and movable relative to fixed contact elements by the magnetomotive force of the field to open and close circuits controlled by the relay, and more particularly to an improved form of polar relay of the character disclosed in my copending application Serial No. 306,690, filed August 27, 1952, the disclosure of which is incorporated herein by reference.

Among the objects of the present invention are to provide an improved relay unit of the character described, in which a more efficient magnetic circuit is provided and considerably more space for the relay coils is obtained without enlargement of the overall dimensions of the relay unit; in which a substantial increase in the stability and sensitivity of the relay is achieved and sticking of the contacts is prevented; to provide means for preventing contact bounce; and the provision of improved means operative to prevent any undesired signal bias in the operation of the relay.

These and other objects and advantages of the invention will be apparent from the following detailed description of an illustrative embodiment thereof, taken in connection with the accompanying drawings in which:

Fig. 1 is a perspective view of a complete relay unit embodying the features of the instant invention;

Fig. 2 is a cross-sectional view taken along the line 2—2 of Fig. 1;

Fig. 3 is a sectional view taken along the line 3—3 of Fig. 2;

Fig. 4 is an enlarged view of the permanent magnet structure and relay contact assembly within an evacuated tube, removed from the unit; and

Fig. 5 is a view taken along the line 5—5 of Fig. 4, showing certain details of the relay contact structure.

Referring particularly to Figs. 1 to 3, the casing of the relay unit comprises a rectangular wall portion **10** composed of a magnetizable material of low reluctance, such as iron, having a cover **11** and a bottom plate member **12**. The members **11** and **12** preferably are of metal. The cover has a circular opening **11***a* therein for a purpose hereinafter explained. As seen in Fig. 3, the bottom plate member **12** receives a duodecal plug **15** of Bakelite or other suitable insulating material, which carries a number of electrical contact prongs **16** adapted to be plugged into a conventional socket. A lower tubular portion **15***a* of the plug body has formed thereon a key or spline (not shown) which is received within a keyway in the socket thereby to insure that the prongs **16** will enter the proper contact sleeves in the socket when the plug is inserted. As seen in Fig. 2, two arcuate strips **15** of Bakelite or other suitable insulating material, and which have tapered edge portions, are interposed between the inner ends or pole pieces of two laminated magnetic cores **18** to position the cores and also the two bobbins **23** that carry the relay windings. A central opening through the unit receives the removable tube **25** that encloses the armature and contact

assembly of the relay. The tube envelope necessarily is composed of a non-magnetic material, and usually is of glass.

Figs. 2 and 3 show a magnetic circuit having a greatly increased efficiency. The laminated cores **18** each is in contact at its outer end with the comparatively thin laminated wall **10** of the casing, so that the relay case provides a return path of low reluctance for the magnetic flux. The inner ends or poles of the cores **18** are tapered and are arcuate, as seen in Fig. 2, thereby to concentrate the flux field in an operating gap immediately adjacent to the wall of the glass tube **25** and the pole pieces **29** (Fig. 4) of the permanent magnet structure within the tube. Referring to Fig. 2, the two opposite laminated wall portions of the casing **12** which are parallel to the longitudinal axis of the cores **18** each extends in a vertical plane as viewed when looking down on the figure, and does not extend appreciably in a horizontal plane. That is to say, the individual laminations or layers of these portions are disposed edgewise instead of flat with respect to the cores and hence do not extend in a horizontal plane towards the cores as in the usual arrangement of magnetic core structures. Therefore the distance, and hence the magnetic leakage path, between the inner ends or poles of each of the cores and the wall portions which comprise the return circuit is greatly increased and is more than one and one-half times, and nearly twice, the distance across the operating gap between the poles, with consequent reduction in magnetic leakage and increase in the amount of flux in the operating gap. With a given number of magnetizing ampere turns applied, this magnetic circuit will, on the average, produce a 40% stronger magnetic field to move the ball armature **35** of the relay than would be produced by a conventional laminated core, for example, as shown in Fig. 23 of my aforesaid application, in which the leakage path from the operating gap at the poles to the adjacent legs of the core is much shorter than that present in the structure of the instant case.

The improved magnetic structure, moreover, provides almost three times as much coil winding space without substantially increasing the overall outside dimensions of the unit. It will be seen from Figs. 2 and 3 that four different relay windings **19** to **22**, such as are commonly employed in telegraph relays, readily are accommodated by the space available between the core structure **18** and the casing **10**. Each relay winding comprises two series-connected coils respectively positioned in opposite halves of the casing as seen in the figures. The coils are wound on two Bakelite bobbins, indicated at **23**, and preferably are separated from the Bakelite bobbins by cellulose acetate sheets; sheets **23'** of this material also are used to separate the various layers of the coil windings. The pieces **14** of Bakelite or other suitable material, shown in Fig. 2, orient the bobbins and their coils properly for the pouring of a thermosetting plastic filler **24**. The Bakelite structure comprising the inner end wall portions of the bobbins **23** may carry eyelets of nickel or the like to provide terminal points both for interconnections of the coils and to facilitate connections to the prongs **16** of the relay base.

The laminated wall portion **10** of the casing may be fabricated from a length of sheet iron of proper width which is wrapped around a form and spot welded or otherwise fastened to form the four sides of a box. The bottom plate **12** which is preferably, although not necessarily, of similar material is drawn in a hydraulic press and pierced to form the opening for the duodecal plug **15**. The bottom plate is spot welded or otherwise secured to the side wall before assembly of the coils in the casing, and this casing assembly preferably is nickel plated to prevent rusting and to improve the appearance. The coils comprising the windings **19** to **22**, with their lami-

nated cores 18 and spacer elements 14, then are assembled in the casing, and all connections between coils and between the windings and the prongs 16 of the plug 15 are made, including a ground lead between the casing and one prong of the plug.

Prior to pouring the plastic filler 24, a cylindrical rod or core plug (not shown) is inserted so that it extends vertically through the casing 10 and is positioned centrally within the opening in the tubular portion 15*a* of the base 15, passing between the inner curved ends of the pole pieces 18 and the arcuate spacers 14, thereby to provide a through aperture slightly larger in diameter than the outer diameter of the tube or capsule 25 subsequently to be inserted. Stearic acid, glyceryl stearate, silicone greases or other known mold-release agents are applied to the core plug to enable ready withdrawal thereof after the molding or filling operation, or a core plug composed of a material which requires no mold-release agent, such as fluoroethylene or "Teflon," may be used.

With the core plug inserted and the outside of the casing 10 greased with a substance such as a silicone grease to prevent any excess filler material from sticking to the outside of the casing, the unit is ready for pouring. The electromagnetic structure is thus embedded in a molded body of a suitable thermosetting insulating material which has high dielectric strength, low power factor, high heat resistance and high arc resistance, and which may be poured as a liquid (preferably heated) and which thereafter hardens. Such a material may comprise cellulose acetate, neoprene or synthetic rubber, or other non-aging plastic insulating compound. Preferably, styrene plastic such as "Melpak IV" or an ethoxyline resin such as "Araldite E–110" is employed, with an associated hardener such as "Araldite HN–901." The E–110 is a hard substance which melts at around 100° C. The proper amount of HN–901, a white powdery substance, is added at between 100° and 120° C. and allowed to dissolve in the molten plastic. While this is taking place, the relay to be poured is placed in an oven and allowed to heat up to nearly the same temperature. When the hardener has completely dissolved, the solution is allowed to rise in temperature to not more than 130° C. and then is poured into the relay case. Care must be taken to pour slowly so that all air is forced out of the case to prevent voids. When pouring is completed, the unit is placed in the oven and cured for about 16 hours at 110° to 120° C. After curing, the plastic is slightly rubbery until cool, when it becomes very hard, after which the top surface is smoothed off and the top cover 11 is put on. The cover may be held in place in any suitable manner, for example, by escutcheon pins. The relay is now ready for the insertion of the tube 25 and its associated elements.

Fig. 4 is a greatly enlarged view of the tube 25 and its enclosed elements. Two pole pieces 29 initially are formed from a small round rod of magnetic material such as soft iron which has the lower end thereof welded to the end of a slightly smaller round rod of stainless steel or other non-magnetic metal or alloy. A hole at 37 and two smaller holes below the first hole are drilled transversely through the rod from which the pole pieces 29 are formed, and this rod and the attached stainless steel rod are sawed in half throughout their combined length to provide the pole pieces 29 and two stainless steel strips 30. Within the small holes in the pole pieces 29 are inserted short rods 39 which preferably are composed of tungsten carbide. These rods or inserts are welded to the pole pieces, and their inner faces are ground to form flat contact surfaces, flush with the inner walls of the pole pieces, which flat surfaces are alternately contacted by the ball armature 35 as signals of opposite polarity are received by the operate windings of the relay.

Between the stainless steel strips is inserted a flat strip 31 of permanent magnet material, for example, a copper-nickel-iron alloy such as "Cunife" or an aluminum-nickel-cobalt alloy such as "Alnico," on the end of which has been welded a thin piece 32 of tungsten carbide or other suitable contact material on which the ball 35 rests. The strip 31 comprises the permanent magnet of the magnetic circuit within the tube, and also connects the contact material 32 to one of the terminals 28 of the tube. Flat strips 33 of mica or other suitable dielectric material insulate the magnet 31 and contact material 32 from the stainless steel strips 30, which steel strips respectively connect the contact members 39 to two other terminals 28 of the tube.

The assembly of elements 30 to 33 is enclosed within an outer cylindrical shell 34 which is spaced therefrom, and in this space is cast glass or "Mycalex" or other plastic molding compound which insulates the enclosed elements from the shell 34 and also locks them in position relative to each other. The strip 31 usually is magnetized after the assembly is completed and sealed in the glass tube. The shell 34 preferably is iron although it may be of any other metal or material, not necessarily magnetic, although it is advantageous to employ a magnetic material since it provides a return path for the flux of the permanent magnet 31. The lead-in wires which pass through the tube may readily be spot welded to the strip 31 and the legs 30 of stainless steel prior to insertion of the assembly within the tube. The large hole which was drilled at 37 causes the pole pieces 29 to be cut away somewhat and this produces a desired concentration of flux around the ball 35. A short cylindrical rod 40 of insulating material is wedged between the arcuate surfaces at 37 to maintain uniform spacing of the pole pieces and also the contact elements 39.

The ball 35 is held in position on the member 32 by the magnetic attraction of the small permanent magnet 31, the ball having an induced vertical magnetic polarization. When the contact assembly is traversed by the horizontal magnetic flux in the operating gap of the relay unit, the ball serves the dual function of armature and moving contact, and rolls to one side contact 39 or the other, depending upon the direction of current flow through the relay coils, and switches the connection from the magnet 31, through the ball, to the proper side contact. The base 27 of the glass tube carries three small machine screws 28, with the lead-in wires of the tube connected under the heads of the screws. The threaded ends of the screws screw into inserts within the molded body 24, one of which inserts is seen in Fig. 3, thereby to secure the tube in proper position within the central aperture in the relay unit, the inserts also serving to electrically connect the terminals of the tube to the prongs 16 of the plug 15. During operation of the ball armature 35 at high speeds, there is a tendency for the pole pieces 29 to be deflected slightly by the force of impact and cause contact bounce between the ball 35 and its contact elements 39. To obviate this, a piece of energy-absorbent material 41 is wedged between the pole pieces 29 and the tube 35. This material is characterized in that it substantially absorbs the shock applied to the pole pieces during operation of the relay and reduces rebound against the ball armature, so that contact bounce is substantially reduced. Preferably, this material is composed of fluorethylene or "Teflon."

After the contact assembly above described is inserted within the tube 25, the latter is exhausted to a high degree of vacuum, less than one micron of mercury pressure, and a getter pill within the tube is fired to give a higher degree of vacuum and to act as a clean-up agent. The tube is then sealed off in known manner, thereby to insure that no arcing will occur between the contact elements within the tube, after which the press of the tube is cemented or otherwise mounted within the base 26. The degree of vacuum should, of course, be sufficiently high to insure that no arcing will occur at the potential of the current controlled by the contact assembly; potentials in excess of 1000 volts may be used with the contact as-

sembly when the tube is exhausted to the degree above mentioned.

In order to magnetically center the relay so that it will operate without bias, an external bias-adjusting magnet 45 disposed within the aperture in the relay unit, Fig. 3, is provided. The magnet preferably is a permanent magnet and is a U type in polarization, and fits over the end of the relay capsule 25 on its longitudinal axis. This bias-adjusing magnet preferably, although not necessarily, is composed of "Alnico V." In contact with and bearing on the upper end of the magnet is a short length of tubing 47 composed of natural or artificial rubber or other suitable resilient material. For clarity the member 47 is shown slightly spaced from the wall of the aperture, but in practice it is slightly wedged within the aperture and is somewhat compressed by means of a brass washer 46 and a coil spring 48, the lower end of which bears against the washer 46 and the upper end of which is held against the top of the casing. The members 47 and 48 resiliently retain the bias-adjusting magnet 45 in any of its adjusted positions. This magnet has means for enabling it to be oriented through the aperture in the relay unit, such as a slot 49 in the upper surface thereof, and bias adjustment can be made with a small screw driver which is passed through the access hole 11*a* in the top of the case and through the spring 48 and the openings in the members 46 and 47. Rotation of the magnet 45 to the proper oriented position causes the ball armature 24 to be magnetically centered so that the relay will operate without bias.

A substantial increase in the stability and sensitivity of the vacuum relay has been achieved by processing the steel ball 24 so that its magnetic characteristics are uniform and to cause it to possess only the required degree of magnetic retentivity or hardness. Prior to this it was found that some of the relays were variable in their characteristics, for example, a relay which at one time could be operated by a 2-milliampere current through its coils might on another occasion require several times this current. By measuring the magnetic characteristics of its steel ball armature, this difficulty was found to be due to an excessive permanent magnetism which built up in the ball. As the ball normally revolves during operation, the strongly magnetized ball would occasionally orient itself so that its magnetism would oppose that of the applied field and produce an apparent sticking of the relay contacts. It was attempted to solve this difficulty by magnetically "softening" the balls so that they would not retain magnetism. These balls were unsatisfactory, however, for they would not revolve during operation and pounded flats at the contact points. The slight turning of the ball at each operation is apparently caused by interaction between the alternating and polarizing magnetic fields applied to the ball and the magnetism remaining in the ball from the preceding operation. These difficulties were solved by controlling the magnetic hardness of the balls to a point where they retain sufficient magnetism to cause rotation but not sticking. Fortunately, the required degree of hardness does not seem to be critical and can be secured by a simple annealing process.

The process of annealing to secure magnetic softness also makes the balls mechanically soft, and after a long period of use such balls may show a slight pattern on their surface which appears to be made up of innumerable very small flat areas. To avoid this effect, the balls may be plated with a hard coating such as chromium, molybdenum, rhodium, tungsten carbide or the like. Instead of a coating the balls may be case-hardened after annealing, by a nitriding process. This consists in heating them for several hours in an atmosphere of ammonia gas. The nitrogen of the gas combines with the surface layer of the steel ball to produce an exceedingly hard nitride coating. Tests on balls thus treated have shown that hundreds of millions of relay operations have failed to produce measurable wear, and results from the tests indicate that billions of operating cycles will be obtained from the relays.

There is no maintenance required during the life of these relays. Since the relays are protected from outside influence such as dust, dirt, moisture, corrosive gases which might cause early and unpredictable failures of contacts, bearings or windings, and since the contacts are the only wearing parts, the relays have very uniform life characteristics. It is expected that the life of the relay contacts under specific operating conditions can be predicted so that the tube 25 can be replaced on a schedule in advance of any failure.

Preferably, as hereinbefore set forth, the tube or envelope which contains the contact assembly is exhausted to a high degree of vacuum so that the gas pressure is so low as to insure that no ionization and arcing will occur. However, it is known in the art that if gases in which the atoms have few electrons, such as hydrogen and helium, are under high pressure, for example, of the order of 15 atmospheres, the mean free path of the electrons is decreased to a value such that there is little or no likelihood that ionization and arcing will occur at the operating potentials employed, and therefore there will be no arcing between the elements of the contact assembly. It will be understood that the tube necessarily would be composed of a heavier glass and that special precautions would be taken for sealing the tube when such high pressures are employed. For brevity in certain of the claims, the expression "non-ionizable medium" is used to define the condition in which the gas pressure is either below or above the range of pressures which would enable ionization and arcing to occur at the potentials with which the tube and its contact assembly are adapted to be used.

Various modifications of the relay and contact assembly of the embodiment shown in the drawings, and various equivalents or substitutes for the elements thereof, readily will occur to those versed in the art without departing from the spirit or scope of the instant invention. The disclosure, therefore, is for the purpose of illustrating the principles of the invention which is not to be regarded as limited except as indicated by the scope of the appended claims.

What is claimed is:

1. A polar relay unit comprising a casing in which the side wall thereof is substantially composed of a laminated magnetic material of low reluctance, magnetic core structure within said casing comprising two laminated legs respectively having two ends thereof positioned adjacent to each other in spaced relation to provide poles with an operating gap between them, the other ends of said legs respectively adjoining two side portions of the laminated wall structure to provide a magnetic flux return path of low reluctance in series with said legs, operate windings positioned around said legs and responsive to received signals for inducing opposite magnetic poles respectively therein, said poles being spaced from said wall structure a distance which is substantially greater than that across said operating gap to minimize magnetic leakage to the return path, said unit having an aperture extending therein and transversely intersecting said operating gap, a sealed tube composed of non-magnetic material and a permanent magnet and an associated armature and contact assembly in a non-ionizable medium enclosed within the tube, the tube being removably positioned in said aperture in the unit with one pole of said permanent magnet adjacent to said opposite magnetic poles and the armature subject to the resultant flux field established in the operating gap.

2. A relay unit according to claim 1, in which said poles of the magnetic core structure are substantially equidistant from the nearest portions of the laminated wall structure and are spaced therefrom a distance greater than one and one-half times the distance across the operating gap between the poles.

3. A relay unit according to claim 1, in which said

legs are in axial alignment with each other and the periphery of the laminated side wall of the casing is substantially rectangular in outline, said casing having two opposite side wall portions each having the laminations thereof extending in a plane substantially parallel to the axis of said legs and spaced from the legs a distance which is substantially greater than the distance across said operating flux gap to minimize magnetic leakage to the return path provided by the casing.

4. A polar relay unit comprising a molded body of insulating material, magnetic core structure within said body comprising two legs respectively having two ends thereof positioned adjacent to each other in spaced relation to provide poles with an operating gap between them, operate windings positioned around said legs and responsive to received signals for inducing opposite magnetic poles respectively therein, said body having an aperture extending therethrough and intersecting said operating gap, a sealed tube composed of non-magnetic material and a permanent magnet and an associated armature and contact assembly in a non-ionizable medium enclosed within the tube, the tube being removably positioned in said aperture in the body with one pole of said permanent magnet adjacent to said opposite magnetic poles and the armature subject to the resultant flux field established in the operating gap, a biasing magnet positioned in said aperture of the body with the external field of the magnet adjacent to said operating gap, said last named magnet having means for enabling it to be oriented, through said aperture, to prevent undesired signal bias during operation of said armature.

5. A relay unit according to claim 4, in which said biasing magnet is a permanent magnet with the opposite poles thereof positioned adjacent to said operating gap, said magnet having means for enabling its poles to be rotated, through said aperture, to orient the external field of the magnet.

6. A relay unit according to claim 4, including resilient means within said aperture for maintaining the biasing magnet in any position to which it is oriented.

7. A relay unit according to claim 4, in which said armature comprises a ball of magnetic material attracted by said permanent magnet and rotatable to selectively engage opposed contacts during operation of the relay, said ball having magnetic retentivity to cause the ball to revolve during successive operations of the relay by the interaction between the magnetic field applied to the ball and the magnetism remaining in the ball.

8. A relay unit according to claim 5, in which the biasing magnet has two legs positioned over an adjacent end of the sealed tube of non-magnetic material.

9. A polar relay unit comprising a casing, magnetic core structure within said casing comprising two laminated legs respectively having two ends thereof positioned adjacent to each other in spaced relation to provide poles with an operating gap between them, operate windings positioned around said legs and responsive to received signals for inducing opposite magnetic poles respectively therein, said casing being filled with a solid insulating compound in which said core structure and relay windings are embedded, said unit including its casing having an aperture extending therethrough and intersecting said operating gap, a sealed tube composed of non-magnetic material and a permanent magnet and an associated armature and contact assembly in a non-ionizable medium enclosed within the tube, the tube being removably positioned in said aperture in the unit with one pole of said permanent magnet adjacent to said opposite magnetic poles and the armature subject to the resultant flux field established in the operating gap, a biasing magnet positioned in said aperture of the unit with the external field of the magnet adjacent to said operating gap, said last named magnet having means for enabling it to be oriented, through said aperture, to prevent undesired signal bias during operation of said armature.

10. A polar relay contact unit comprising a sealed tube composed of non-magnetic material, a permanent magnet and an associated armature and contact assembly in a non-ionizable medium enclosed within the tube, said contact assembly including an element having a contact surface adjacent to one pole of said magnet and two other conducting members of magnetizable material respectively having oppositely disposed contact surfaces, said armature comprising a conductive ball of magnetic material attracted by said permanent magnet and rotatable on said first named contact surface to selectively contact said oppositely disposed contact surfaces in response to changes in polarity in the magnetic flux field of a polar relay for closing a circuit between either of these surfaces and said first named contact surface, said ball having magnetic retentivity to cause the ball to revolve during successive operations of the relay by the interaction between the magnetic field applied to the ball and the magnetism remaining in the ball, said ball being annealed to limit its retentivity to a predetermined value to prevent sticking between the ball and either of said oppositely disposed contact surfaces.

11. A polar relay contact unit according to claim 10, in which said armature is an annealed steel ball having a hard outer surface to minimize wear.

12. A polar relay contact unit according to claim 11, in which said annealed ball is case hardened to provide a hard outer surface to minimize wear.

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