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MAGNETIC STICK RELAY

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FIG. 1.

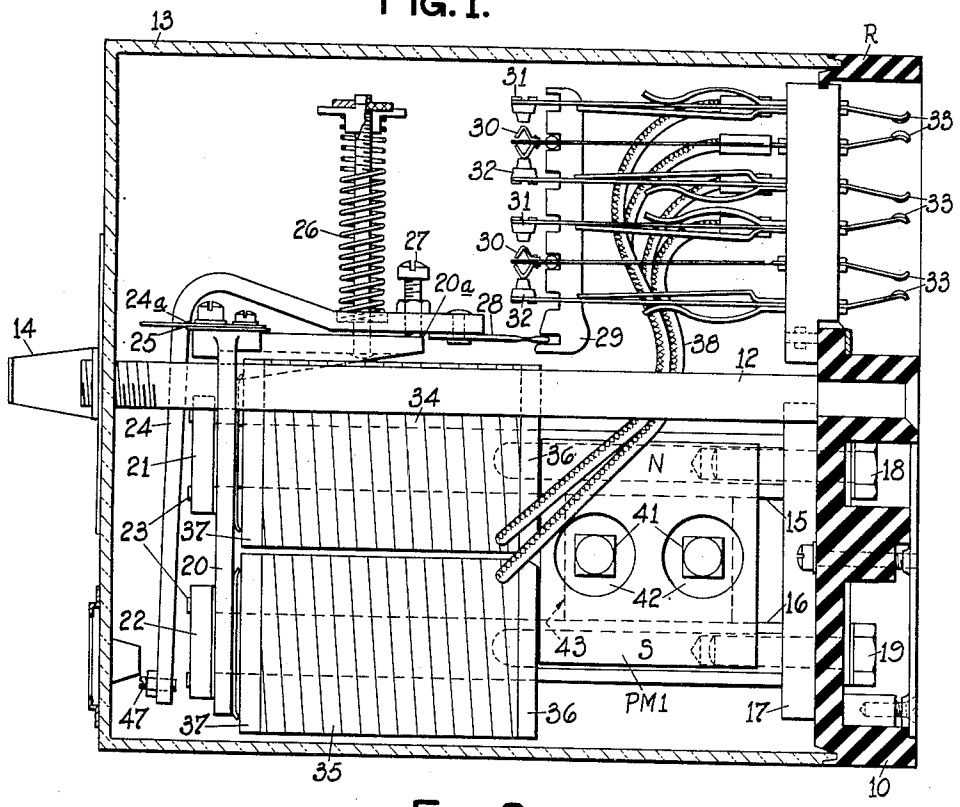
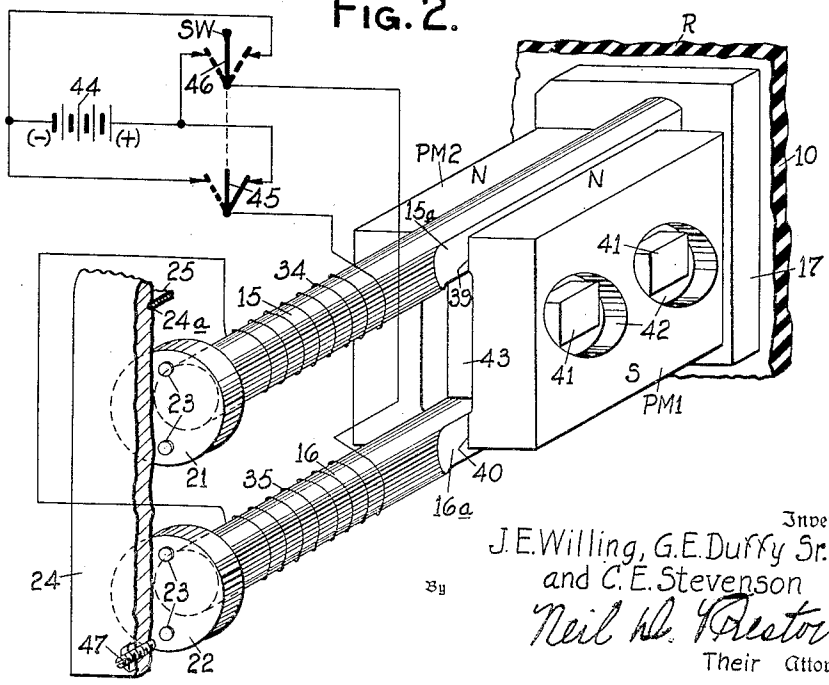


FIG. 2.



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MAGNETIC STICK RELAY

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4 Claims. (Cl. 175—339)

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This invention relates to direct current relays, and it more particularly pertains to two-position relays actuated to one position or the other in accordance with the polarity of its energization and maintained in its last operated position when electrical energy is removed.

This application is a continuation in part of our prior application Ser. No. 697,452 filed September 17, 1946, now abandoned; and claim to all subject matter of such prior application is made in this application.

A relay of this character, conveniently called a magnetic stick relay, has its armature held in its attracted position by a permanent magnet after energy of a polarity to cause the attraction of the armature has been removed from the relay windings. The armature is restored, or knocked down, to its opposite position by the energization of the windings with the opposite polarity, and is maintained in such opposite position by a biasing spring and/or gravity acting against the attraction of the permanent magnet through an increased air gap. Because of the possibility of the armature of a magnetic stick relay being picked up by the permanent magnet alone if such armature is moved slightly toward the pole faces as by vibration, the use of such a relay has been generally limited to functions not involving safety such, for example, as for indicating purposes and the like.

It is an object of the present invention to provide a magnetic stick relay that is sufficiently dependable in its operation to have a greater range of application because of its adaptability to withstand severe vibration without its armature being picked up by its permanent magnet alone. This is accomplished, generally speaking, by employing a relatively stiff spring for biasing the armature to its restored position, in combination an efficient electromagnetic means for attracting the armature. The use of the stiff spring limits the excursions of the armature during vibration to prevent the armature from becoming sufficiently close to the pole faces of the core structure of the relay to be attracted by the permanent magnet alone.

Another object of the present invention is to provide a magnetic stick relay of the tractive type which requires substantially the same energizing current value of reverse polarity in its windings to knock its armature down as it does of normal polarity to pick its armature up.

Other objects, purposes and characteristic features of the present invention will be in part obvious from the accompanying drawings and in part pointed out as the description progresses.

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In describing the invention in detail, reference will be made to the accompanying drawing in which corresponding reference characters identify corresponding parts of differene views and in which:

Fig. 1 an elevational view of a relay constructed according to the present invention with certain parts shown in cross section; and

Fig. 2 is a perspective view of certain of the relay elements with certain parts shown schematically for illustrating the mode of operation of the relay.

Although it will be readily apparent as the description progresses that the present invention is applicable to other forms of relays than the relay R shown in Fig. 1, the disclosure of the present invention is facilitated by applying it to the plug board type of relay as shown in Fig. 1 because reference can be made to the Merkel U. S. Patent No. 2,258,123 dated October 7, 1941, for a more complete disclosure as to the details of the structure of the relay R, the adjustment of the armature spring pressure, and the manner in which the relay R is readily detachable from a plug board.

For an understanding of the present invention it is believed sufficient to consider the relay R of Fig. 1 as having a base member 10 adapted to be secured to a plug board by suitable rods, preferably of non-magnetic material, extending through the non-magnetic tubes 12 which are suitably secured to the base member 10. A cover 13, preferably of transparent material, is secured over the relay contacts and the operating mechanism to protect them against dust and mechanical damage, such cover being retained by the bracket 14 which is threaded on to the end of the tube 12.

The relay cores 15 and 16 of low reluctance magnetic material such as silicon steel are secured to a transverse yoke 17 of similar material connecting the cores 15 and 16 at their right-hand ends, and to the base 10, by the screws 18 and 19 respectively.

The left-hand ends of the cores 15 and 16 are spaced by a bracket 20 of non-magnetic material, the bracket 20 being fitted over the cores 15 and 16 and over the tubes 12. The pole faces 21 and 22 of the cores 15 and 16 respectively are suitably secured to the bracket 20 as by the rivets 23, such rivets being of non-magnetic material to serve also as residual pins for providing a minimum spacing of the armature 24 away from the ends of the cores 15 and 16. Such spacing in practice is generally about ten thousandths of an inch.

The armature 24 is formed to extend across the pole faces 21 and 22 and such armature is pivoted at the point 24a by the knife edge bearing 25. The adjustable spring 26 acts to bias the armature 24 away from the pole faces to an extent limited by the adjustment screw 27 striking the non-magnetic bracket 20 at the point 20a.

Connected to the armature 24 is an operating lever 28 engaging the pusher 29 which is of insulating material and which operates the movable contact fingers 30 to close front contacts 31 or back contacts 32 in accordance with the respective attracted or restored positions of the armature 24. The contact tips 33 serve to provide a means of detachably coupling the respective contact fingers to a suitable plug board (not shown).

The relay windings 34 and 35 are assembled over the respective cores 15 and 16, and they are restricted against longitudinal movement by the permanent magnets PM1 and PM2. The spacers 36 of insulating material at the right-hand end of the windings 34 and 35 insulate such windings from the permanent magnets PM1 and PM2; and the spacers 37 at the left-hand end of the windings 34 and 35 insulate such windings from the non-magnetic bracket 20.

Each of the windings 34 and 35 has its lead wires 38 suitably attached to respective contact tips 33 to provide for their detachable connection to contacts of a plug board (not shown). Although only one vertical row of contact tips 33 is shown in Fig. 1, it is to be understood that other rows of tips are provided for the connection of the respective lead wires 38 and for the connection of other contact fingers than those illustrated.

The permanent magnets PM1 and PM2 are clamped on opposite sides of the cores 15 and 16, and they have like poles associated with the respective cores. The cylindrical cores 15 and 16 have flat finished surfaces 15a and 16a respectively (see Fig. 2) for contacting the finished surfaces at points 39 and 40 of the permanent magnet PM1. Although not as clearly illustrated, the magnet PM2 is similarly fitted against the cores 15 and 16 on the opposite side from the permanent magnet PM1. The flattened portions 15a and 16a at the right hand ends of the cores 15 and 16 causes the cores to be of reduced cross-section. It will be noted that the cross-section of the permanent magnets PM1 and PM2 is substantially greater than the cross-section of the cores 15 and 16 so that a strong magnetic field may be set up in the cores, even though the actual length of the magnets must be short because of the short lateral spacing between the cores 15 and 16.

Although the permanent magnets PM1 and PM2 may be formed of several different types of permanent magnet material, it has been found that the material identified by the trade name of Alnico Red Streak Steel is particularly satisfactory because of the high coercive force required to demagnetize it. The magnets PM1 and PM2 are securely clamped to the cores 15 and 16 by the bolts 41 which have their heads recessed into the cavities 42 formed in the permanent magnets. The spacer block 43 of non-magnetic material is disposed between the magnets PM1 and PM2 to limit the strain on the magnets when the bolts 41 are drawn tight, and such spacer also serves to properly align the magnets PM1 and PM2 with the cores 15 and 16.

To consider the mode of operation of the relay R, it will be assumed that such relay is used in a circuit which can be energized with one polarity or the other or can be deenergized. A circuit of this character is shown, for example, in Fig. 2 which shows the switch SW as having a center position in which the windings 34 and 35 of the relay are deenergized, a right-hand position in which the windings 34 and 35 are energized with one polarity, and a left-hand position in which the windings 34 and 35 are energized with the opposite polarity. The armature 24 is illustrated in Fig. 2 as being in its restored position because it is assumed that the relay R was last energized with a polarity to cause it to be knocked down as by the operation of the switch SW to its right-hand position.

With no energy applied to the electromagnet, the lines of flux of the respective permanent magnets is divided into two magnetic circuits. One circuit for the permanent magnet PM1 can be traced from the upper pole of the permanent magnet PM1, through the left-hand portion of the core 15, the armature 24, and the left-hand portion of the core 16, to the lower pole of the permanent magnet PM1. Another magnetic circuit for the permanent magnet PM1 extends from the upper pole of that magnet, including the right-hand end of the core 15, the yoke 17, and the right-hand end of the core 16, to the lower pole of the permanent magnet PM1. The magnetic circuits for the permanent magnet PM2 are the same and have the same polarity.

Assuming the switch SW to be operated to its left-hand position for applying energy to the windings 34 and 35 of the relay for picking up the armature 24, a circuit becomes energized extending from the positive terminal of the battery 44 including contact 46 of the switch SW in its left-hand position, relay winding 35, relay winding 34 and contact 45 of the switch SW, to the negative terminal of the battery 44.

The energization of this circuit causes a flux to be set up in the electromagnet to establish the pole face 21 as a north pole, and the pole face 22 as a south pole. It will be obvious from Fig. 2 that the poles of the electromagnet thus established at the pole faces 21 and 22 correspond with the poles established at such pole faces by the flux of the permanent magnets. In other words, the electromagnetic flux is established in a direction to add to the flux of the permanent magnets PM1 and PM2 through the armature 24 to an extent to actuate the armature 24 to its attracted position limited by engagement with the non-magnetic residual pins 23 and the adjustable non-magnetic residual screw 47.

The reduction of the air gap between the armature 24 and the pole faces 21 and 22 by the picking up of the armature 24 provides a magnetic circuit of sufficiently low reluctance that a sufficient number of lines of flux from the permanent magnets PM1 and PM2 links the armature 24 to maintain such armature in its picked up position after the switch SW is restored to its center position to open the circuit which has been described for the energization of the windings 34 and 35 at contacts 45 and 46.

To consider the mode of operation of the relay R for the restoration of the armature 24 to its knocked-down position, it will be assumed that the switch SW is operated to its right-hand position to cause the energization of the windings 34

and 35 with the opposite polarity from that employed for picking up the relay. With the switch SW in its right-hand position, the windings 34 and 35 are energized by a circuit extending from the positive terminal of the battery 44, including contact 45 of switch SW in its right-hand position, relay winding 34, relay winding 35 and contact 46 of the switch SW in its right-hand position, to the negative terminal of the battery 44.

The energization of the windings 34 and 35 as described above, with the switch SW in its right-hand position, establishes an electromagnetic flux in the left-hand ends of the relay cores 15 and 16 in a direction to oppose the flux of the permanent magnets PM1 and PM2 to an extent to weaken the total flux in the armature 24 and its working air gap and thus allow the action of the relatively stiff armature spring 26 to restore the armature 24 to its restored, or knocked-down, position.

When the armature 24 is operated to its knocked-down position, the air gap between the armature 24 and the pole faces 21 and 22 is increased to an extent to render the flux set up by the permanent magnets PM1 and PM2 through the armature 24 of insufficient strength to attract the armature 24 to its picked-up position without the aid of the electromagnet.

In connection with the theory of operation of the relay R, it should be noted as previously pointed out, that the permanent magnets PM1 and PM2 provide flux for two magnetic circuits, one magnetic circuit extending through the armature 24, the air gaps, and the portions of the cores 15 and 16 to the left of the permanent magnets PM1 and PM2, and the other magnetic circuit extending through the yoke 17 and the flattened portions 15a and 16a of the cores to the right of the permanent magnets PM1 and PM2. It will be noted that the latter magnetic circuit through the yoke 17 is shorter than the other magnetic circuit through the armature and air gaps, and also includes no air gap, so that it is of low reluctance and may become substantially saturated.

Assuming energy to be applied to the windings 34 and 35 of the electromagnet with a polarity for picking up the armature 24, the electromagnetic flux set up in response to such energization of these windings acts in series, so to speak, with the permanent magnets to strengthen the magnetic flux already existent in the magnetic circuit through the armature 24 and its air gaps. If the permanent magnets PM1 and PM2 provided the only path for the magnetic flux produced by such energization of the windings 34 and 35, the increase in flux through the armature and its air gaps would be limited by the high reluctance of these permanent magnets. However, there is another magnetic circuit for the electromagnetic flux, due to such energization of the windings 34 and 35, through the soft iron yoke 17 and reduced portions 15a and 16a of the cores 15 and 16. The magnetomotive force provided by the energization of the windings 34 and 35 for picking up the armature 24 is in a direction to send flux through this other magnetic circuit including the yoke 17 in an opposite direction to the flux provided by the permanent magnets PM1 and PM2, so that if any part of this magnetic circuit, such as flattened core portions 15a and 16a are of such cross section as to be substantially saturated by the permanent magnets PM1 and PM2, the electromagnetic flux of the pick-up energization of the windings 34 and 35 is in an opposite direction to the permanent magnet flux and may readily pass through this magnetic circuit. It is by use of this magnetic circuit for electromagnetic flux that the electromagnet is made sufficiently efficient to cause attraction of the armature dependably with low values of operating current.

Let us now consider the case where the armature 24 is being held in its attracted position by the flux of the permanent magnets PM1 and PM2, and the windings 34 and 35 are energized with current of the other or reverse polarity to knock down the armature. Under such conditions, the magnetomotive force due to such reverse energization of the windings tends to create flux in the cores 15 and 16 through the armature 24 in a direction opposite to the flux being provided by the permanent magnets PM1 and PM2; and the resultant flux through the armature 24 is thus reduced sufficiently for its biasing spring 26 to move it to its retracted or knocked down position. In order that the armature 24 may thus be knocked down, the magnetomotive force created by the reverse or knock-down energization of the windings 34 and 35 has to be sufficient to reduct the flux from the permanent magnets through the armature 24 below the value needed to overcome the force of the biasing spring 26 while the armature 24 is in its attracted position and the air gap between it and the pole pieces 21 and 22 is at minimum; but in the various applications and uses of the relay, the reverse or knock-down energization of the windings 34 and 35 may be greater than this operating value, due to variations in the source of voltage and the like, and these windings may provide a magnetomotive force greater than needed to neutralize the holding effect of the permanent magnets upon the armature 24. In order that such excess energization of the winding with reverse or knock-down polarity, which may be maintained for sometime after the armature 24 has assumed its retracted position, may not provide sufficient flux in the reverse direction through the armature and air gap to either hold the armature 24 attracted or pull it back again to its attracted position, the magnetic circuit through the yoke 17 and the reduced portions 15a and 16a of the cores to the right of the permanent magnets PM1 and PM2 are proportioned so as to be substantially saturated by the permanent magnet flux, or at least magnetized to a degree that this magnetic circuit is not capable of conducting much more flux in the same direction as the permanent magnet flux.

In this connection, it will be noted that the energization of the windings 34 and 35 with the reverse or knock-down polarity tends to send flux through the flattened core portions 15a and 16a and yoke 17 in the same direction as the permanent magnets PM1 and PM2. With such proportioning of the parts, the windings 34 and 35 may be energized with current of the reverse polarity much more than needed to release the armature, and still not cause the armature to be again attracted, since the magnetic circuit through the yoke 17 is then substantially saturated for flux having a direction as produced by the reverse or knock-down energization of these windings. Hence, the energizing current of the reverse polarity may assume values much greater than needed to release the armature without causing the armature to be picked up again. This enables the relay to be properly operated with wide variations in its operating currents.

Since it is usually desirable to operate such a relay from a single source of energy, it is desirable in the interests of efficiency for the relay to have the same pick-up and drop-away values, and at the same time have an adequate margin of safety against false pick-up by an over-energization of the relay by reverse or knock-down polarity.

One way of adjusting the relay of this invention to obtain these characteristics is to first adjust the biasing spring 26 to the value required to hold the armature down against the vibrations and shocks to which it may be subjected. Such a biasing means is provided not only to give back contact pressure but to also prevent the armature from being picked up by the permanent magnet flux alone both normally and under conditions of vibration which might occur and cause small reductions to be made in the air gap by slight excursions of the armature under such conditions.

With the bias spring pressure thus selected, the permanent magnets are then caused to have the proper strength so that the pick-up and drop-away values of energization of the windings 34 and 35 are the same. If the pick-up value is greater than the drop-away value, then the permanent magnet is too weak. On the other hand, if the drop-away value is higher than the pick-up value, then the permanent magnet is too strong. In fact, pick-up and drop-away curves may be plotted for different strengths of the magnets. These respective pick-up and drop-away curves when plotted on the same coordinates intersect each other because such curves vary in opposite relationships. That is, as the permanent magnet strength is increased the pick-up operating current decreases, while the knock-down current increases as magnets of greater strength are employed. The point of intersection of the two curves represents the particular permanent magnet strength that can be used in the combination with the selected biasing spring pressure to give the same pick-up and knock-down values of current. The operating value of current for the relay for this particular strength of permanent magnet should of course be as low a value as possible particularly when the relay is to be remotely controlled over a line circuit where it is desirable to conserve power.

This feature of providing the same pick-up and drop-away values for a relay of this type could not be obtained in prior art relays since sufficient protection against erroneous pick-up by reverse polarity could not be obtained. When the pick-up and release values were made the same in such prior art relays, a fairly small increase in reverse pick-up current would either cause the armature to hold up, if the reversal was quick, or cause it to erroneously pick-up again after it had been released. Also, a slight decrease in biasing spring pressure, or a slight decrease in magnetic strength, as a result of wear and ageing would cause the relay to be subject to the undesired reverse pick-up upon a relatively small increase in current. For this reason, the prior art relays usually required greater pick-up current values than drop-away current values with compensating resistors employed for the different polarities of energization of the relay windings.

As previously explained, the magnetic circuit of the present relay including back yoke 17 and the reduced core sections 15*a* and 16*a* is substantially saturated when the reverse or knock-down polarity of energization is applied to the windings 34 and 35. For this reason, these windings are relatively inefficient for producing flux through the armature and its working air gaps upon such reverse energization. Because of this characteristic of the relay structure to render the windings inefficient to produce flux beyond the amount required to oppose the permanent magnet flux and cause the armature to drop away, the relay may be constructed to have the same or comparable pick-up and drop-away values for normal working voltages without any improper operation of the armature in the case of excessive reverse energization. In fact, the application of energy of reverse polarity of several times the normal working voltages will neither cause the armature to remain picked up nor cause it to be again picked up after the armature has once been knocked down. In one form of relay constructed to embody the principles of the present invention, it has been found that over eight times normal working voltage must be applied in the reverse direction before the armature will pick up. This assures the proper operation of the relay under all circumstances in spite of variations in the voltage supply or in the deterioration of biasing springs, magnets or the like.

Having thus described one specific magnetic stick relay as one embodiment of the present invention, it is desired to be understood that this form is selected for the purpose of facilitating the disclosure of the present invention rather than to limit the number of forms which the present invention may assume, and it is to be further understood that various adaptations, alterations and modifications may be applied to the specific forms shown to meet the requirements of practice without in any manner departing from the spirit or scope of the present invention except as limited by the appending claims:

What we claim is:

1. A magnetic stick relay for attracting and releasing a biased armature in response to energization of opposite polarities respectively and also maintaining said armature in its last actuated position during deenergization of the relay, said relay comprising in combination, a pair of cores with enlarged pole pieces at corresponding ends, a permanent magnet and a yoke of magnetic material connected across said cores at their other ends, said yoke providing a magnetic shunt path for said permanent magnet and such path being proportioned with respect to said permanent magnet to be substantially saturated by the permanent magnet alone, a movable armature extending across said pole pieces, said armature being biased to its retracted position by a force permitting said permanent magnet alone to hold said armature in its attracted position in opposition to said biasing force but preventing said permanent magnet alone from moving said armature from its retracted position, a winding located on said cores between said permanent magnet and said pole pieces, said winding when energized with one polarity of current acting to send flux through said pole pieces and armature in addition to the flux provided by said permanent magnet and thereby actuate said armature to its attracted position, said winding when energized with the opposite polarity of current of a comparable intensity acting to reduce the flux through the pole pieces and armature provided by said permanent magnet and thereby cause said armature to assume or remain in its retracted position, said permanent magnet being of a ma-

terial to withstand the demagnetizing effect of energization of said winding with such opposite polarity, said armature under the influence of the permanent magnet alone and while said winding is deenergized remaining in the attracted or retracted position resulting from the immediately preceding energization of said winding.

2. A magnetic stick relay for actuating a biased armature in response to the polarity of energization of the relay and also maintain said armature in its last actuated position during deenergization of the relay, said relay comprising a pair of parallel cores connected at one end by a magnetic back yoke and having enlarged pole pieces at the other end, a permanent magnet connected across said cores adjacent said yoke, coils on said cores between said permanent magnet and said pole pieces, a movable armature cooperating with said pole pieces and biased to its retracted position by a force permitting said permanent magnet alone to maintain said armature in its attracted position but preventing actuation of said armature from its retracted position by the permanent magnet alone, said yoke being proportioned with respect to said permanent magnet to be substantially saturated by the flux from the permanent magnet alone, said coils when energized with one polarity acting to add to the magnetic flux through said pole pieces and armature as provided by said permanent magnet and thereby actuate said armature from its biased position to its attracted position, the magnetic flux in said yoke provided by the energization of said coils with said one polarity being in a direction opposite to the direction of permanent magnet flux and thereby enabling said yoke to provide an efficient magnetic circuit through the armature for the flux provided by the energization of said coils with said one polarity, said coils when energized with the opposite polarity acting to oppose the flux of the permanent magnet through said pole pieces and armature and thereby cause said armature to move to or to remain in its retracted position, said permanent magnet being of a material to withstand the demagnetizing effect of energization of said winding with such opposite polarity, the magnetic flux in said yoke provided by the energization of said coils with said opposite polarity being in the same direction as the direction of the permanent magnet flux already saturating said yoke thereby rendering said coils inefficient in the production of magnetic flux through said armature when thus energized with such opposite polarity so that many times its normal energization will not cause improper actuation of said armature, said armature under the influence of said permanent magnet alone and while said coils are deenergized remaining in the position to which it was last actuated by the polarity of energization of said coils.

3. A magnetic stick relay of the type described for actuating a biased armature in response to the polarity of energization and also maintaining said armature in its last operated position during deenergization, said relay comprising, a pair of parallel cores connected at one end by a back yoke of limited cross section and having enlarged pole pieces at the other end, a permanent magnet clamped across said cores adjacent said yoke, said yoke being substantially saturated with flux from said permanent magnet, coils on said cores located between said permanent magnet and said pole pieces, a pivoted armature extending across said pole pieces, an adjustable

spring for biasing said armature to its retracted position, the biasing force of said spring permitting the flux from said permanent magnet alone to hold the armature in its attracted position but preventing movement of the armature from its retracted position by the flux from the permanent magnet alone, said coils when energized with one polarity acting to provide flux in a magnetic circuit through said armature and including said cores and yoke with such flux in the pole pieces and armature being in the same direction as the flux from said permanent magnet and thereby overcoming the force of said biasing spring to move the armature to its attracted position, said coils when energized with current of the opposite polarity acting to oppose the permanent magnet flux through the armature and thereby cause said armature to assume or remain in its retracted position, said permanent magnet being of a magnetic material capable of maintaining its magnetic strength under the influence of the electromagnetic flux when such coils are energized with said opposite polarity, the magnetic flux in said yoke provided by the energization of said coils by current of said opposite polarity being in the same direction as the flux produced therein by the permanent magnet, said yoke being substantially saturated by the permanent magnet flux alone acting to increase the reluctance of the magnetic circuit through the armature to magnetic flux tending to be produced by energization of said coils by current of said opposite polarity, thereby reducing the tendency for the armature to be actuated to its attracted position by energization of said coils with current of said opposite polarity, said permanent magnet acting alone and while said coils are deenergized to cause said armature to remain in the position last actuated by the polarity of energization of said coils.

4. A magnetic stick type relay for attracting and releasing a biased armature in response to energization of currents of opposite polarities respectively and also maintaining said armature in its last actuated position while the relay is deenergized, said relay comprising in combination, a pair of cores with enlarged pole pieces at corresponding ends and with portions of reduced cross-section at their other ends, a yoke of magnetic material connected across said cores at their said other ends, a permanent magnet located adjacent said yoke and making intimate magnetic connection with said two cores at their portions of reduced cross-section and being so proportioned relative to said cores and said yoke as to cause the substantial magnetic saturation of the shunting magnetic path including said yoke, a movable armature pivoted adjacent said pole pieces with an intervening working air-gap but said armature being biased away from such pole pieces by a force preventing flux from said permanent magnet alone from attracting said armature to a picked up position but such force being sufficiently small to permit flux from the permanent magnet to hold said armature in picked up position, windings located on said cores between said yoke with its adjacent permanent magnet and said pole pieces, said windings when energized with current of one polarity being effective to produce flux through said working airgap and armature in addition to the flux provided by said permanent magnet to thereby attract said armature to its picked up position, said windings when energized with current of the opposite polarity acting

to reduce the permanent magnet flux through the airgap and armature and thereby allow said armature to assume its biased position, said permanent magnet being of such material and having such a residual magnetism as to allow the attraction and release of said armature in response to the same degree of energization of said windings with said currents of opposite polarities respectively without losing such residual magnetism.

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GEORGE E. DUFFY, SR.
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