

May 28, 1963

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ELECTRO-MAGNETIC DEVICE

3,091,725

Filed Aug. 28, 1958

2 Sheets-Sheet 1

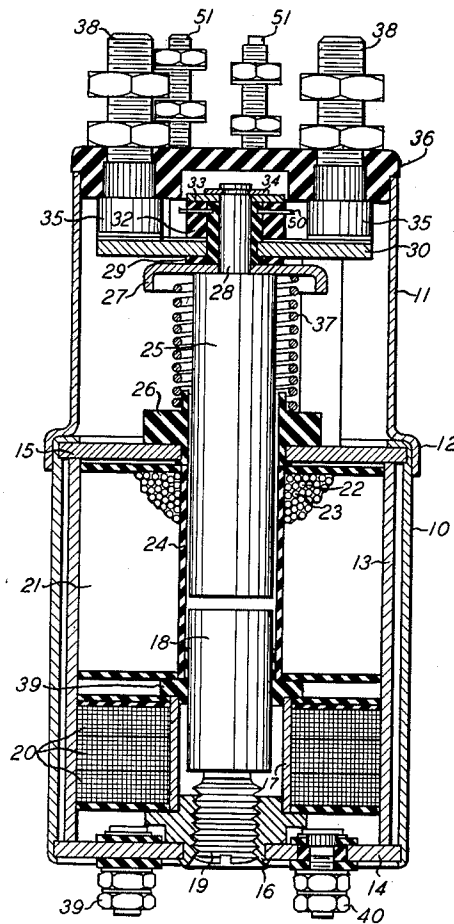


FIG. 1

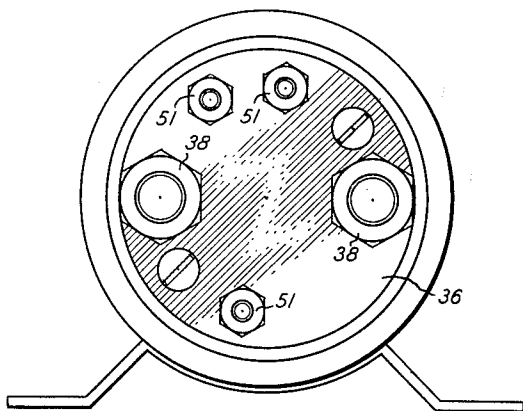


FIG. 2

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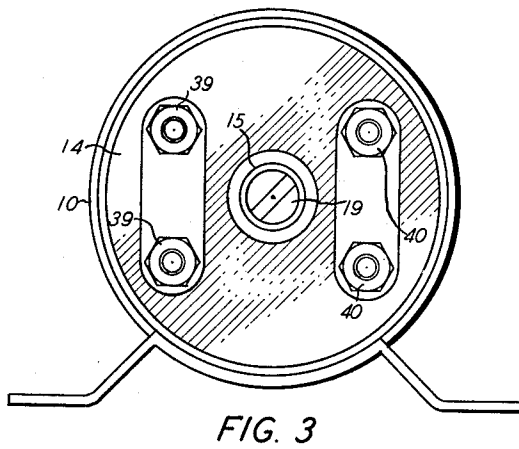
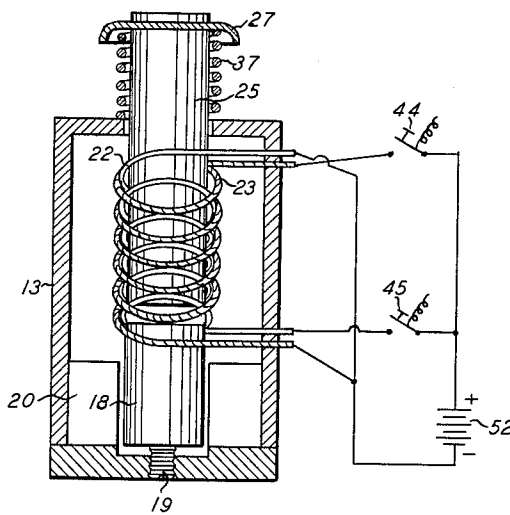
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ELECTRO-MAGNETIC DEVICE

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Filed Aug. 28, 1958, Ser. No. 757,724

8 Claims. (Cl. 317-171)

This invention relates to an electrically-operated device, and more particularly to a solenoid device having an armature which is operated by the energizing of an electro-magnetic coil, and is held in its operated position by a permanent magnet.

Prior solenoid devices were so constructed that they required a constant flow of energizing current to maintain their armatures in an operated position. Thus, to maintain an electrical contact or a mechanical lever device, which is operably connected to an armature of a solenoid, in one of its operating positions, the coil of the electro-magnet must be constantly energized.

In view of the above, one of the objects of this invention is to provide an improved solenoid device which can be impulse operated to open a circuit, and so constructed that the circuit will remain open until positively closed by a subsequent impulse.

A further object of this invention is to provide an improved solenoid device of the type in which the armature is held in an operated position by a permanent magnet.

A still further object of this invention is to provide an improved solenoid device having mechanical means for adjusting the length of the armature stroke, and the strength of the magnetic field necessary to move the armature to an operated position.

A still further object of this invention is, to provide an improved spring biased solenoid device having a self-aligning armature.

A still further object of this invention is to provide an improved solenoid device which is powerful in its movement, positive in its operation, and able to meet many individual requirements in its operating characteristic.

A still further object of this invention is to provide an improved solenoid device which is compact in construction, and economical to manufacture.

Other objects, purposes and characteristic features of this invention will be obvious from the accompanying drawings, the specification, and the appended claims.

In the drawings:

FIG. 1 is a cross-sectional view of a solenoid device constructed according to one embodiment of this invention, showing the armature in a retracted position;

FIG. 2 is a plan view of the solenoid device;

FIG. 3 is a bottom plan view of the solenoid device; and

FIG. 4 is a diagrammatic view of the solenoid device showing a typical operating circuit.

This embodiment of the invention illustrates a solenoid device which is adaptable to open and close a pair of heavy duty electrical contacts in response to an impulse of energizing current.

The solenoid device is housed in a cylindrical housing formed of members 10 and 11, which are secured together at a bent flange 12 formed on the housing portion 11. The cylindrical members 10 and 11 may be formed of any suitable material in accordance with the individual requirements of practice. A cylindrical housing comprising an iron sleeve 13, which is closed at one end by a disc shaped non-magnetic cover 14, made, for instance, of aluminum, and at the other end by a disc shaped iron cover 15 is coaxially mounted within the cylindrical mem-

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ber 10. The cover 14 has a central opening therein which is fitted with an annular supporting block 16 made, for instance, of steel, which axially extends into the interior hollow portion of the sleeve 13.

A solid cylindrical pole piece 18 having a threaded end 19 is adjustably threaded into the opening of the supporting block 16, and axially extends into the interior of the cylindrical sleeve 13. The threaded portion 19 of the pole piece 18 provides a means for axially adjusting the pole piece 18 in the sleeve 13.

An iron sleeve 17 which is mounted coaxially within the sleeve 13 and radially spaced therefrom, is supported by a shoulder of the supporting block 16. A plurality of stacked ring shaped radially polarized permanent magnets 20 surround the sleeve 17 and are interposed between the sleeve 13 and the sleeve 17. The permanent magnets 20 are supported by the shoulder of the block 16.

Although the permanent magnets 20 may be composed of any suitable magnetic material which will withstand high external demagnetizing forces, the preferred magnet is a ceramic magnet made of ferrite materials such as certain combinations of barium carbonate and iron oxide. The high coercive characteristics of this type of magnet results in a large crystal anisotropy of the ceramic material which resists demagnetization. Although a plurality of stacked ring shaped magnets 20 are shown herein, it is understood that one or more such magnets of varying degrees of thickness can be provided in accordance with the individual needs of practice.

The axially extending pole piece 18 is made from a soft magnetic material which has a relatively high degree of permeability. The pole piece 18 becomes permanently magnetized by the influence of the permanent magnets 20 with a magnetic field of the same polarity as the permanent magnets 20.

A tubular or ring shaped electro-magnetic coil assembly 21, comprising wound coils 22 and 23, is mounted on a spool 24 having a central opening therein. The spool is coaxially mounted in the sleeve 13 above the permanent magnets 20. The lower part of the opening of the spool 24 surrounds the upper portion of the pole piece 18. The flanges of the spool 24 engage the interior surface of the cylindrical sleeve 13. Interposed between the stack of permanent magnets 20 and the electro-magnetic coil assembly 21 is a tubular guide bushing 39, which slidably surrounds the intermediate portion of the cylindrical pole piece 18. The guide bushing 39 has a flange which serves to maintain proper spacing between the upper surface of the permanent magnets 20 and the lower surface of the electro-magnetic coil assembly 21. The bushing 39 also serves to maintain proper axial alignment of the pole piece 18 with the electro-magnetic coil assembly 21 and the permanent magnets 20.

The coil 22 of the electro-magnet 21 is wound in one direction about its spool 24 so that when it is energized, it produces a magnetic field of the same polarity as that of the permanent magnets 20. The coil 23 of the electro-magnet 21 is wound about its spool 24 in a direction opposite to that of coil 22 so that when coil 23 is energized it produces a magnetic field which opposes the polarity of the permanent magnets 20. Although a double wound coil is shown, the single coils of which, are selectively energized to produce a magnetic field of one polarity or the other; it is understood that two separate coils may be employed, or an electro-magnet having a single coil or winding may be employed which is adapted to be pole-changed by an exterior circuit connection.

A solid cylindrical armature 25 extends through a central opening in the cover 15 and into the central opening of the spool 24 of the electro-magnet assembly 21 along the same axis as the pole piece 18. Interposed between

the armature 25 and the disc cover 15 is a flanged bushing 26. The inner surface of the flanged bushing 26 is spaced from the outer surface of the armature 25, and is supported by the top surface of the cover 15.

The upper end of the armature 25 is provided with a rigidly attached stud 28. A dish shaped cap washer 27 having a downwardly curved peripheral flange, surrounds the stud 28. The cap washer 27 is held in position against a shoulder on the armature 25 by a grommet 29, which has a flange at its lower end. The grommet 29 surrounds the stud 28, and is axially secured in relation thereto, by a washer 33 and a lock washer 34.

Interposed between the washer 33 and surrounding the grommet 29, is a contact retaining bushing 32. The contact retaining bushing 32 serves to rigidly secure a contact plate 30 in position above the dish shaped member 27. The contact plate is spaced and insulated from the dished plate 27 by the flange of the grommet 29. There is also provided a contact plate 50, which is spaced from, and is disposed transversely to the contact plate 30, and is rigidly secured to the retaining pin 28. The upper end of the cylindrical housing member 11 is covered by an inter-fitting cap 36 carrying appropriate terminal posts 38 which extend therethrough to electrically connect with contacts 35, which are so disposed as to firmly contact the plate 30 when the armature 24 is in a retracted position.

Thus, it is apparent that the operated or downward movement of the armature 25 will separate the contact plate 30 from the contacts 35. The contact plate 50, which extends transversely to the contact plate 30, is adapted to engage a similar set of contacts (not shown) which are electrically connected to the terminal posts 51. Interposed between the lower surface of the dish shaped member 27 and the upper flanged surface of the bushing 26 and surrounding the armature 25 is a coil spring 37.

In the normal position shown in FIG. 1, the force of the spring 37 against the lower surface of the plate 27 and the upper surface of the bushing 26 maintains the armature 25 axially spaced from the upper end of the pole piece 18; and the contact plate 30 is in electrical contact with contacts 35. The spring 37 also serves to maintain the armature 25 in proper axial alignment with the electro-magnetic coil assembly 21, thus rendering aligning bearings or such unnecessary.

The lower cover 14 is provided with two pairs of terminal posts 39 and 40, respectively, which extend through said cover 14, but are insulated therefrom. The pair of terminal posts 39 are adapted to be connected to a source of energizing current 52 (see FIG. 4) for energizing the coil 22 of the double wound electro-magnet assembly 21, which produces a magnetic field having a polarity the same as the polarity of the permanent magnets 20. The terminal posts 40 are adapted to be suitably connected to the source of current 52 for energizing the coil 23 of the electro-magnetic assembly 21 to produce a magnetic field having a polarity opposite the polarity of the permanent magnets 20.

When the solenoid device is in a normal position as shown in FIG. 1, the armature 25 is held in a retracted position by the force of the coil spring 37. The magnetic field of the permanent magnets 20 and of the pole piece 18 tends to compress the coil spring 37 to draw the armature 25 downward to an operated position. However, because of the axial distance between the upper end of the pole piece 18 and the permanent magnets 20, the armature 25 is not in the concentrated flux of the permanent magnetic field, and therefore, the permanent magnets 20 are unable to overcome the force of the coil spring 37 to draw the armature 25 downward.

Referring to FIG. 4 the solenoid device is operated by closing a contact button 44 which connects the terminals 39 to a suitable source of direct current 52, thereby energizing the coil 22 of the electro-magnetic assembly 21. The energizing of the coil 22 produces a magnetic field having a polarity the same as the magnetic field of the

permanent magnets 20. The increased intensity of the magnetic field caused by the augmenting field of the electro-magnet compresses the spring 37 and draws the armature 25 inward to an operated position against the top surface of the pole piece 18. The contact button is opened after the coil 22 has been sufficiently energized to bring the armature 25 into that part of the permanent magnetic field having the greatest flux density, which is close to the pole piece 18. The armature 25 is held in its operated position by the force of the permanent magnet 20 and the pole piece 18, without the aid of the magnetic field of the coil 22. Thus, it is seen that a short impulse of generating current to the coil 22 brings the armature 25 into close proximity with the pole piece 18 and its operation is completed solely by the flux of the permanent magnets 20.

To return the armature 25 to its retracted or normal position a switch 45 is closed, thereby connecting the terminal points 40 to the current source 52, which energizes the coil 23 of the electro-magnet assembly 21, thereby producing a magnetic field having a polarity opposite the polarity of the permanent magnets 20. The generation of a magnetic field opposite to that of the permanent magnets 20 assists the biasing force of the coil spring 37 and opposes permanent magnets, thereby permitting the coil spring 37 to withdraw the armature 25 to its retracted position. Thus, it is apparent that an impulse of current sufficient to energize coil 23 to generate a magnetic field of sufficient intensity to overcome the holding effect of the permanent magnets 20 is sufficient for operating the armature 25 to its retracted position.

By axially adjusting the pole piece 18 by means of its threaded portion 19, the magnetic field of the permanent magnets 20 is moved closer to, or farther away from the armature 25. This adjustment also varies the axial distance which the armature 25 moves in order to assume a fully operated position.

Assuming that the pole piece 18 is axially moved away from the face of the armature 25, the magnetic field of the coil 22 must build up to a greater flux density in order to draw the armature 25 within the influence of the magnetic field of the permanent magnets. Similarly, if the pole piece 18 is axially adjusted so that it is closer to the surface of the armature 25, the distance which the armature 25 will travel to assume a completely operated position is much shorter. It also follows that the magnetic field of the permanent magnets 20 is moved closer to the armature 25 thereby requiring a lesser flux density of the magnetic field produced by the coil 22 to attract the armature to its operated position. The pole piece 18 can also be adjusted to compensate for variable strength of the coil spring 37. Therefore, not only is the axial movement of the armature 25 adjustable, but it also follows that the amplitude of the impulse required to operate the armature is directly proportional to such adjustable length.

This apparatus may be used to open the battery powered circuit of an automotive vehicle upon imparting an impulse to the device, so that power may be completely cut off, thus minimizing danger of fire or explosion. It also may be used for the remote operation of mechanical levers such as door locks in an apartment house, or the opening and closing of fluid pressure valves. This apparatus is also useful in the remote opening and closing of heavy duty electrical contacts, such as are used in starting circuits for electric motors, or output circuits for generators.

While the invention has been described in connection with a specific embodiment thereof, it will be understood that it is capable of further modification, and this application is intended to cover any variations, uses, or adaptations of the invention following, in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practice in the art to which the invention pertains, and as

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may be applied to the essential features hereinbefore set forth, and as fall within the scope of the invention or the limits of the appended claims.

Having thus described my invention, what I claim is:

1. An electrically operated device, comprising a housing, operating coil means mounted in said housing, a permanent magnet positioned in said housing to create a magnetic field of a definite polarity, said permanent magnet being axially spaced from said coil means, an armature movably mounted in said housing, spring means connected to said armature constantly urging said armature away from said permanent magnet to a first position, means for energizing said coil means to create a magnetic flux of the same polarity as said permanent magnet, said coil flux and said permanent magnet flux having sufficient force to move said armature towards said permanent magnet to a second position against the pressure of said spring means, said permanent magnet having sufficient force to retain said armature in said second position after it has been moved thereto although said coil means be subsequently deenergized, means for energizing said coil means to create a magnetic flux of opposite polarity to oppose the holding force of said permanent magnet and enable said spring means to move said armature back to said first position, and means connecting said permanent magnet, said coil means, and said armature in a closed magnetic circuit when said coil means is energized.

2. An electrically operated device comprising a casing, an elongate armature mounted in said casing to move axially therein, a permanent magnet having a bore therethrough mounted in said casing, a pole piece mounted in said casing and extending axially through the bore of said permanent magnet and projecting at one end beyond the corresponding end of said permanent magnet, spring means constantly urging said armature axially away from said permanent magnet and out of contact with said pole piece, an electromagnetic coil means mounted in said casing and surrounding at least a portion of said armature and part of said pole piece but spaced from said permanent magnet, means for energizing said coil means with current flowing in one direction to create a magnetic flux of the same polarity as said permanent magnet to augment the flux of said permanent magnet to move said armature toward said permanent magnet into contact with said one end of said pole piece, the force of said permanent magnet being effective to hold said armature in contact with said pole piece after said armature has been brought into contact therewith though said coil means be subsequently deenergized, means for energizing said coil means with current flowing in the opposite direction to create a magnetic flux of opposite polarity to overcome the pull of said permanent magnet to cause said spring means to move said armature away from said permanent magnet and out of contact with said pole piece, and means connecting said permanent magnet, said coil means, and said armature in a series magnetic circuit when said coil means is energized.

3. An electrically operated device, comprising a casing, a pole piece attached to said casing at one end thereof, a permanent magnet mounted in said casing at said one end, said permanent magnet having a central bore which surrounds said pole piece for at least a portion of the length of said pole piece, an elongate armature mounted in said casing in axial alignment with said bore to move towards and away from said pole piece, spring means connected to said armature and constantly urging said armature away from said pole piece, an electromagnetic coil means mounted in said casing between said permanent magnet and said spring means and surrounding said armature, means for energizing said electromagnetic coil means to create a magnetic flux of the same polarity as said permanent magnet, said electromagnetic coil flux and said permanent magnet flux together having sufficient strength to move said armature axially into contact with said pole piece, said permanent magnet having sufficient force to

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hold said armature in engagement with said pole piece against the pressure of said spring means after said armature has been brought into contact with said pole piece though said coil means be subsequently deenergized, means for energizing said coil means to create a magnetic flux of opposite polarity therein overcoming the force of said permanent magnet to cause said spring means to move said armature away from said permanent magnet and out of contact with said pole piece, means for adjusting said pole piece axially of said bore toward and away from said armature, and means connecting said permanent magnet, said coil means, and said armature in a series magnetic circuit when said coil means is energized.

4. An electrically operated device comprising a casing, a ring-shaped permanent magnet secured in said casing, an armature reciprocally mounted in said casing in axial alignment with said magnet for movement toward and away from said magnet, a spring connected to said armature and constantly urging said armature in one direction away from said magnet to a first position, a pair of oppositely wound electrical coils mounted in said casing and surrounding said armature but spaced from said permanent magnet, said coils being connectable to a unidirectional source of current, and means for connecting one coil to said source of current to energize said one coil to create a flux aiding that of said permanent magnet to move said armature against the pressure of said spring toward said magnet to a second position, said permanent magnet being of sufficient strength to retain said armature in said second position when said one coil is deenergized, means for connecting the other coil to said source of current to energize said other coil to create a flux in opposition to that of said permanent magnet to permit said spring to move said armature back to said first position, and means connecting said permanent magnet, one of said coils, and said armature in a series magnetic circuit when one of said coils is energized.

5. An electrically operated device comprising a hollow casing made of paramagnetic material, an armature slidably mounted in said casing, an electrical coil means mounted within said casing and surrounding said armature, a permanent magnet mounted in said casing but spaced axially from said coil means, a spring connected to said armature and constantly urging said armature away from said permanent magnet to a first position spaced therefrom, means for supplying current to said coil means to create a magnetic flux in one direction which cooperates with the magnetic force continuously exerted by said permanent magnet to move said armature to a second position against the resistance of said spring, said permanent magnet having sufficient force to retain said armature in said second position after it has been moved thereto although said coil means be subsequently disconnected from said current supplying means, said armature, when in said second position closing a magnetic circuit from one pole of said magnet through said armature and said casing back to the other pole of said magnet, means for supplying current to said coil means to create therein a magnetic flux in a direction to oppose the holding force of said permanent magnet thereby to enable said spring to move said armature back to said first position, and means connecting said permanent magnet, said coil means, and said armature in a closed magnetic circuit when current is supplied to said coil means.

6. An electrically operated device comprising a hollow casing made of paramagnetic material, an armature slidably mounted in said casing, an electrical coil mounted within said casing and surrounding said armature, a permanent ring-shaped magnet mounted in said casing in axial alignment with said coil and axially spaced from said coil and having a centrally-disposed bore, a soft-iron pole piece mounted in said bore in axial alignment with said armature and extending into said coil, a spring connected to said armature and constantly urging said armature away from said pole piece to a first position spaced there-

from, means for supplying current to said coil to create a magnetic flux in one direction which cooperates with the magnetic force continuously exerted by said permanent magnet to move said armature to a second position against the resistance of said spring in which it is in contact with said pole piece, said permanent magnet having sufficient force to retain said armature in said second position after it has been moved thereto although said coil be subsequently disconnected from said current supplying means, said armature when in said second position closing a magnetic circuit from one pole of said magnet through said pole piece, armature and casing back to the other pole of said magnet, means for supplying current to said coil to create therein a magnetic flux in a direction to oppose the holding force of said permanent magnet and pole piece thereby to enable said spring to move said armature back to said first position, and means for adjusting said pole piece axially of said bore toward and away from said armature.

7. An electrically operated device comprising a hollow casing, an armature movably mounted in said casing, a ring-shaped permanent magnet, an operating coil means surrounding said armature, spring means normally biasing said armature in one direction to a first position spaced from said permanent magnet, means for supplying current to said coil means to create a magnetic flux which is in one direction and is in series with the force exerted by said permanent magnet whereby said flux and force are additive and move said armature in the opposite direction to a second position against the resistance of said spring means, said permanent magnet having sufficient force to retain said armature in said second position after it has been moved thereto although said coil means be subsequently disconnected from said current supplying means, and means for supplying current to said coil means to create therein a magnetic flux in a direction to oppose the holding force of said permanent magnet, thereby to enable said spring means to move said armature back to said first position, said permanent magnet being axially spaced from said coil means so as not to be affected by the magnetic flux created in either direction in said coil means.

8. A magnetically latching electrical solenoid comprising a casing of a magnetic material, a magnetic armature reciprocable in said casing, an electrical coil within said casing and surrounding said armature, a permanent magnet within said casing spaced axially from said coil and contacting at its periphery with said casing, a pole piece of relatively low coercive force material extending axially from said magnet into said coil, and a spring for biasing said armature to a first position away from said pole piece, the strengths of said spring and said magnet being selected relative to each other so that (a) when said armature is moved into contact with said pole piece, said magnet is capable of retaining said armature against the biasing force of said spring, and (b) when said armature is spaced from said pole piece, said magnet is insufficient by itself to move said armature toward said pole piece, said casing having a wall extending transversely of said armature so that when said armature contacts said pole piece said armature substantially closes a relatively low reluctance flux circuit for said magnet, said circuit extending through said pole piece, said armature, and said casing, means for energizing said coil to create a magnetic flux in one direction which cooperates with the magnetic force continuously exerted by said permanent magnet to move said armature to a second position against the resistance of said spring, said permanent magnet having sufficient force to retain said armature in said second position after it has been moved thereto although said coil be subsequently deenergized, and means for supplying current to said coil to create therein a magnetic flux in the opposite direction to oppose the holding force of said magnet thereby to enable said spring to move said armature back to said first position.

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