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said retaining flange thereby to obstruct the normal return movement of said lever and to prevent return movement of said leaf spring.

6. In an electric tool having a casing, a hollow handle, an electric motor in said casing and a motor-controlling switch unit removably mounted in said handle and having a shiftable switch-actuating lever normally biased to one of two predetermined positions and provided with an abutment surface; the improvement which consists in the provision of a locking device for said switch-actuating lever comprising a member mounted on and removable with said switch unit and normally maintained out of the path of movement of said abutment surface, and a manually shiftable element carried by said handle and engaging said member for moving it into the path of movement of said abutment surface thereby to obstruct the normal return movement of said lever.

7. A locking device for a switch unit having a spring pressed switch-actuating lever normally biased to a switch opening position and having in its side face an undercut abutment surface; comprising a leaf spring mounted flatwise adjacent

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that side face of the lever having said abutment surface and normally maintained out of the path of movement of said lever, and a manually actuated element, operable when said lever is pressed to its switch closing position, to deflect said leaf spring sidewise into the path of movement of said abutment surface so that when pressure on said lever is relieved and said lever moves forwardly slightly said abutment surface is engaged with said leaf spring to hold the lever in switch closing position, said leaf spring automatically moving out of the path of said abutment when said lever is again moved in a switch closing direction.

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ELECTRODYNAMIC RELAY

Albert Cohen, United States Navy

Application December 11, 1945, Serial No. 634,333

10 Claims. (Cl. 200—110)

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1 This invention relates in general to electrical relays, and in particular to electrodynamic relays.

Relays of the solenoid or electromagnet type are used conventionally and for most purposes have been found quite successful. These relays, however, require a relatively large operating current, while in certain instances the necessity arises for a relay that will operate in response to a very feeble current, for example, a current of the order of a few milliamperes.

An object of this invention, therefore, is to provide an extremely sensitive electrical relay that can control the switching of relatively large currents with a very feeble operating current.

Another object is to provide an electrical relay employing a moving coil in a permanent magnetic field.

A further object is to provide an extremely sensitive relay that is compact in construction and relatively impervious to surrounding conditions.

Further objects and advantages of this invention, as well as its construction, arrangement and operation, will be apparent from the following description and claims in connection with the accompanying drawing, in which the single figure is a sectional elevation view of one embodiment of the electrodynamic relay of this invention.

The electrodynamic relay consists of three main parts: a magnet 10, a moving coil 12, and a contact assembly 14. The magnet 10 is preferably a permanent magnet of the high-permeability type, such as known to the art under the trade names of "Alnico" or "Permalloy." Use of an electromagnet, however, is within the scope of this invention. This magnet 10 is cylindrical in shape and is supported by any convenient means within a magnetic frame 16 of steel or other magnetizable material, which is provided with a core 17. An annular air-gap 18 is provided between the core 17 and collar 19 of the frame 16. The moving coil 12 is mounted for free motion within the air-gap upon a thin-walled cylinder 20, of paper or other lightweight non-conducting material, which is supported as by diaphragms 22, of paper, leather or other suitable flexible material, in such manner as to permit axial movement of the cylinder 20. Diaphragms 22 are in turn secured as at 23 within a housing 24, which may be also cylindrical in shape. The movable coil 12 consists of a multiplicity of turns of very fine wire, insulated by enamel or other suitable material.

On the end of the movable cylinder 20 distal 55

2 the coil 12 is mounted a contact assembly 14. This assembly comprises a conductor 25 having contact points 26 at its ends, and attached to the movable cylinder 20 by a non-conducting pin 28 and washers 30 and 32.

Arranged within the casing 24 so as to make contact with the contacts 26 upon axial movement of the cylinder 20 are two pairs of contact terminals 34 and 36. Electrical connections 38 and 40 are provided for contact terminals 34 and 36 and electrical connections 42 are provided for the moving coil 12. These connections extend through casing 24 at terminal 44. This terminal and all other openings and joints in the casing 24 are preferably sealed hermetically. The entire relay assembly can optionally be sealed hermetically within the casing 24, thus making it impervious to dirt, moisture and other conditions. Long life of the unit is thereby assured.

The operation of this relay depends upon the well known principle of the Ampere law: $F = BIL$, where F represents the mechanical force exerted by a magnetic field upon a wire carrying current, B is the strength of the magnetic field, I is the instantaneous electric current, and L is the length of the wire carrying the current I in the magnetic field. An analysis of this formula shows that for a large value of B and a long length of wire L , it will require a comparatively small quantity of current, I , to produce the required amount of mechanical force to move the contacts from one position to another. The superior sensitivity of this relay depends upon this principle.

In operation, the contact assembly is set so that one pair of contact terminals is connected electrically by conductor 25 and contact points 26. A weakly-energizing current through the moving coil 12 then causes the contact assembly to move axially, thereby breaking the connection between the connected contacts and completing the connection between the other pair of contact terminals. If desired, one pair of contact terminals can be omitted and the device used merely to make or break connections in one circuit. Optionally, the moving coil can be made to move in either one direction or the reverse by reversing the polarity of the applied voltage. In other instances, it is advantageous to adjust the contact assembly so that a circuit is complete when a steady current is flowing through the moving coil 12 and when the current in this coil fluctuates this circuit is broken, and, optionally, another circuit completed. Also, by adjusting the mechanical resonance of the moving coil assembly, the relay can be made to operate only at a partic-

ular frequency of alternating current. These and other variations of the contact assembly will be apparent to one skilled in the art.

In addition to moving sets of contacts as illustrated, this relay can also be arranged to actuate a switch of the snap-action type, such as the type known under the trade-names of "Microswitch" or "Acro Switch," or it can operate a mercury-pool type switch.

An important advantage of this relay over relays of the solenoid or magnetic-attraction type lies in its superior sensitivity. Other advantages are its adaptability to be directional, its high speed of operation, resistance to shock, and its adaptability to hermetic sealing.

Various modifications and changes can be made in the subject device without departing from the scope of the invention.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

I claim:

1. An electrodynamic relay comprising a magnet of high permeability and a magnetizable frame providing an air-gap, a casing upon said frame, a movable coil assembly within said casing and extending within said air-gap, means for supporting said movable coil assembly radially upon said casing, said movable coil assembly being movable axially within said casing and air-gap in response to an energizing current through said coil, a pair of contact terminals within said casing, and a contact element on said movable coil assembly adapted to connect electrically said contact terminals upon said axial movement.

2. An electrodynamic relay comprising a magnet of high permeability and a magnetizable frame providing an annular air-gap, a casing upon said frame, a cylinder within said casing extending within said annular air-gap, non-metallic diaphragm means supporting said cylinder radially upon said casing, a coil upon the portion of the cylinder within said air gap, electrical connections for said coil extending through said casing, said cylinder and coil being movable axially within said casing and air-gap in response to an energizing current through said coil, a pair of contact terminals within said casing, and a contact element associated with said movable cylinder adapted to connect electrically said contact terminals upon said axial movement.

3. An electrodynamic relay comprising a frame of magnetizable material having a core forming an annular space therein, a cylindrical permanent magnet of high permeability within said annular space and embracing said core, said core and said frame forming an annular air-gap spaced from said magnet, a casing embracing said frame, a cylinder of non-conducting material mounted for axial movement upon said casing and extending into said annular air-gap, a coil around said cylinder within said air-gap and having electrical connections extending through said casing, said cylinder and coil assembly being movable axially in response to an energizing current through said coil, two pair of electrical contact terminals mounted within said casing, and a bridging contact element mounted upon said movable cylinder and adapted upon axial movement of said cylinder in one direction to connect one of said pair of contact terminals and upon axial movement of said cylinder in the reverse direction to connect the other pair of contact terminals.

4. An electrodynamic relay comprising a magnet of high permeability and a magnetizable frame providing an air-gap, a casing upon said frame, a movable coil assembly within said casing and extending within said air-gap, a non-metallic and flexible frustum-shaped element supporting said movable coil assembly radially upon said casing, said movable coil assembly being movable axially within said casing and air-gap in response to an energizing current through said coil, a pair of contact terminals within said casing, and a contact element on said movable coil assembly adapted to connect electrically said contact terminals upon said axial movement.

5. An electrodynamic relay comprising a magnet of high permeability and a magnetizable frame providing an annular air-gap, a casing upon said frame, a cylinder within said casing extending within said annular air-gap, diaphragm means comprising a pair of opposed, non-metallic and flexible frustum-shaped elements supporting said cylinder upon said casing, a coil upon the portion of the cylinder within said air-gap, electrical connections for said coil extending through said casing, said cylinder and coil being movable axially within said casing and air-gap in response to an energizing current through said coil, a pair of contact terminals within said casing, and a contact element associated with said movable cylinder adapted to connect electrically said contact terminals upon said axial movement.

6. An electrodynamic relay comprising a frame of magnetizable material having a core defining an annular recess in said frame, a cylindrical permanent magnet of high permeability within said recess and encircling said core, said core and said frame forming an annular air-gap spaced from said magnet, a casing embracing said frame, a cylinder of non-conducting material mounted upon said casing for axial movement within said casing and extending into said annular air-gap, a coil around said cylinder within said air-gap and having electrical connections extending through said casing, said cylinder and coil assembly being movable axially in response to an energizing current through said coil and being secured within said frame by means comprising a plurality of non-metallic flexible supporting diaphragms, two pair of electrical contact terminals mounted within said casing, and a contact element mounted upon said movable cylinder and adapted upon axial movement of said cylinder in one direction to connect one of said pair of contact terminals and upon axial movement of said cylinder in the reverse direction to connect the other pair of contact terminals.

7. An electrodynamic relay comprising a magnet of high permeability and a magnetizable frame providing an air-gap, a casing sealed hermetically upon said frame, a movable coil assembly within said casing and extending within said air-gap, a non-metallic and flexible frustum-shaped element supporting said movable coil assembly radially upon said casing, said movable coil assembly being movable axially within said casing and air-gap in response to an energizing current through said coil, a pair of contact terminals within said casing, and a contact element on said movable coil assembly adapted to connect said contact terminals upon said axial movement.

8. An electrodynamic relay comprising a magnet of high permeability and a magnetizable frame providing an annular air-gap, a casing

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sealed hermetically upon said frame, a cylinder within said casing extending within said annular air-gap, diaphragm means comprising a pair of opposed, non-metallic and flexible frustum-shaped elements supporting said cylinder upon said casing, a coil upon the portion of the cylinder within said air-gap, electrical connections for said coil extending through a hermetically sealed port in said casing, said cylinder and coil being movable axially within said casing and air-gap in response to an energizing current through said coil, a pair of contact terminals within said casing, and a contact element associated with said movable cylinder adapted to connect said contact terminals upon said axial movement.

9. An electrodynamic relay comprising a frame of magnetizable material having a core defining an annular recess in said frame, a cylindrical permanent magnet of high permeability within said recess and encircling said core, said core and said frame forming an annular air-gap spaced from said magnet, a casing embracing said frame and sealed hermetically thereon, a cylinder of non-conducting material mounted upon said casing for axial movement within said casing and extending into said annular air-gap, a coil around said cylinder within said air-gap and having electrical connections extending through a hermetically sealed port in said casing, said cylinder and coil assembly being movable axially in response to an energizing current through said coil and being secured within said frame by a plurality of non-metallic flexible supporting diaphragms, two pair of electrical contact terminals mounted within said casing, and a contact element mounted upon said movable cylinder and adapted upon axial movement of said cylinder in one direction to connect one of said pair of contact terminals and upon axial movement of said cylinder in the reverse direction to connection the other pair of contact terminals.

10. An electrodynamic relay comprising a frame of magnetizable material having a core defining an annular recess in said frame, a cylindrical

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permanent magnet of high permeability within said recess and encircling said core, said core and said frame forming an annular air-gap spaced from said magnet, a casing embracing said frame and sealed hermetically thereto, said casing comprising a sleeve portion affixed to said frame and a cap portion carried on the end of said sleeve portion distal said frame, a cylinder of non-conducting material positioned for axial movement within said casing and extending into said annular air-gap, a coil around said cylinder within said air-gap, said coil having electrical connections extending through a hermetically sealed port in the cap portion of said casing, said cylinder and coil assembly being movable axially in response to an energizing current through said coil and being secured within said casing by a plurality of frusto-conical, non-metallic, flexible supporting diaphragms, said diaphragms being secured between the sleeve and cap portions of said casing, two pair of electrical contact terminals mounted within said casing, and a contact element mounted upon said movable cylinder and adapted upon axial movement of said cylinder in one direction to connect one of said pair of contact terminals and upon axial movement of said cylinder in the reverse direction to connect the other pair of contact terminals.

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