

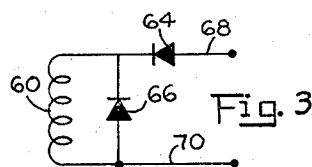
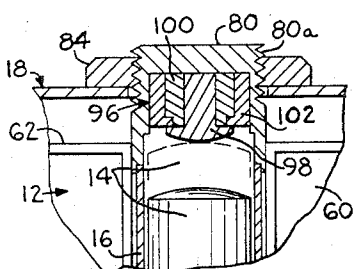
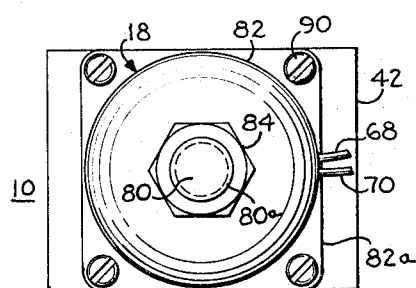
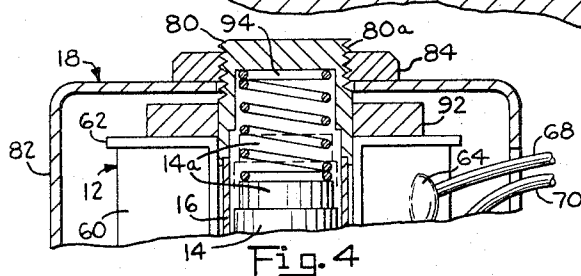
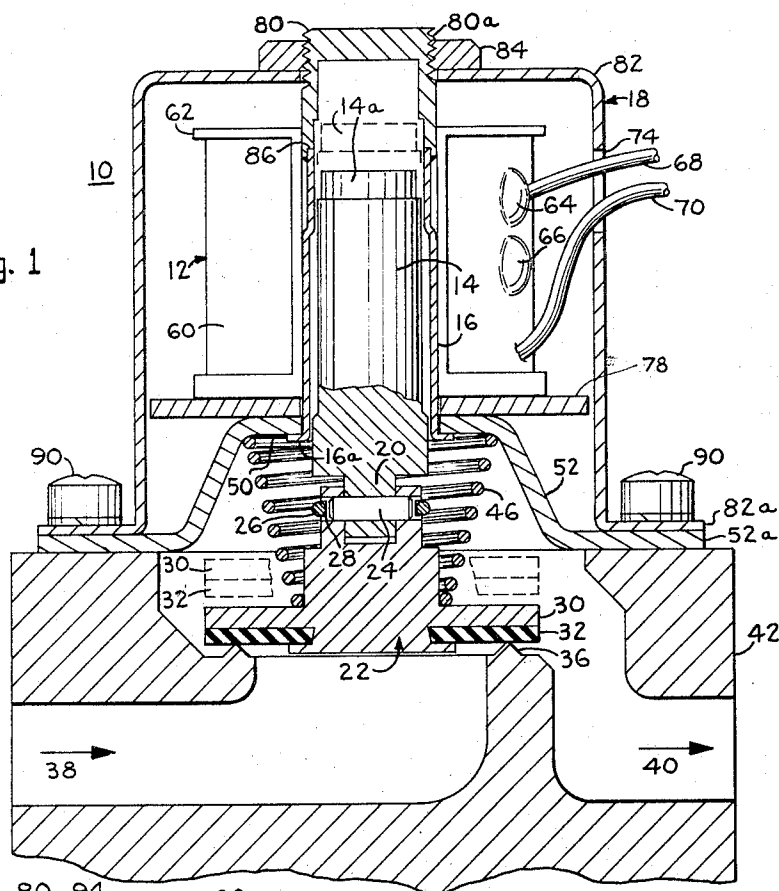
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G. E. DIETZ ETAL
ELECTROMAGNETIC ACTUATOR

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Fig. 1



GERALD E. DIETZ INVENTOR.
RUSSELL B. MATTHEWS
BY *G. J. DeAngelis*
ATTORNEY

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3,378,732

ELECTROMAGNETIC ACTUATOR

Gerald E. Dietz, Milwaukee, and Russell E. Matthews, Oconomowoc, Wis., assignors to Penn Controls, Inc., Goshen, Ind., a corporation of Indiana
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ABSTRACT OF THE DISCLOSURE

A non-impact solenoid in which the path of the plunger is extended beyond the coil end by means of a hollow magnetic cap which terminates one end of the non-magnetic plunger guide. When the coil is energized, the plunger attains a magnetic "null" position without impacting the end cap. This null position is attained by balance of the magnetic forces interconnecting the plunger with the end cap and a substantially large washer of magnetic material positioned encircling the open end of the plunger guide.

The invention relates to electromagnetic actuators and especially to those equipped for energization from an alternating current source.

Electromagnetic actuators adapted for energization from alternating current sources, in general, comprise an energizing electromagnetic coil mounted encircling a sleeve or tube of non-magnetic material in which a plunger is slidably disposed for guided movement along the coil axis. The plunger is usually biased by a spring toward a normally unactuated position. A magnetic circuit path is provided for the flux generated by the coil by a magnetic frame upon which the coil is mounted. The path is such as to cause the flux to magnetically couple the plunger, under conditions where the coil is energized, to actuate the plunger against its spring bias along the coil axis. The magnetic frame includes a pole piece terminating one end of the guide sleeve of the plunger. The pole piece acts as an end stop which the plunger strikes when it is actuated. To prevent "drop-out" of the plunger and also "chatter" of the plunger against the pole piece during variations of the flux (due to the inherent cycling of the alternating current source) a shading ring is provided encircling the depending pole piece within the guide sleeve. This shading ring acts as a "shorted" turn in which induced current flow creates sufficient flux to maintain the plunger in its actuated position against the pole piece preventing "drop-out" and "chatter." Such actuators, because of the necessity that the plunger strike the pole piece, are noisy.

In certain applications of electromagnetic actuators it is desirable that their operation be completely noiseless. In other applications, although some operating noise may be tolerated, what may be termed "quiet" operation is desirable.

It is, therefore, an object of the invention to provide an electromagnetic actuator adapted for energization from an alternating current source, which actuator is readily adaptable to various applications, and yet is of simple construction, reliable in operation, and may be economically manufactured and maintained.

It is another object to provide such an electromagnetic actuator which is noiseless.

It is yet another object to provide such an electromagnetic actuator which, while not completely noiseless, is of substantially quiet operation being free of the noise due to impact of the plunger against a stop and of "hum" type noise.

Still another object is to provide such an actuator which

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may be readily and simply assembled and disassembled into any one of three desired constructions, that is, the completely noiseless, the quiet, or the impact type actuator.

The invention involves providing for noiseless operation an electromagnetic actuator with two rectifiers connected in the circuit of its energizing coil, one to provide half-wave rectified direct current for energizing the coil, and the other connected directly across the coil to provide a current path which tends to maintain the flux field generated by the coil during variations of the applied current. The plunger and magnetic circuit are constructed such that the plunger is actuated to a "null" position where the net magnetic forces acting upon it balance the biasing force of its spring to maintain the plunger in such position so long as the coil remains energized. The plunger is brought and maintained in this actuated position without impact against a stop, and maintained there without noise which may be termed "hum." One end of the plunger is stepped or necked down slightly to conform to the configuration of a magnetic end cap closing one end of the guide sleeve in which the plunger is disposed to provide a fixed air gap between the plunger and the magnetic end cap, when the plunger is in its actuated position. This fixed air gap prevents the plunger being maintained actuated after its energizing coil is disconnected from the alternating current source.

To provide a "quiet" operating actuator, the foregoing described actuator is modified by omitting the rectifier shunting the coil and substituting therefor a relatively large shading ring of copper, encircling the end cap terminating the guide sleeve. The shading ring acts as a shorted turn and is of sufficient mass that currents induced therein by the collapse of the generated flux field produce sufficient flux during the blocked half-cycle of the applied power to maintain the plunger magnetically coupled in its "null" position and minimizing A.C. "hum." This construction requires no impact of the plunger against a stop and maintains the plunger in an actuated position by balancing the magnetic forces acting on the plunger against the force of the biasing spring.

To provide the impact type actuator, the first described actuator is modified by removing both rectifiers from the coil circuit and by providing a pole piece and encircling shading ring of copper within the guide sleeve at the capped end, against which pole piece the plunger strikes and is maintained by the shading ring.

Features and advantages of the invention may be seen from the above, from the following descriptions of the preferred embodiments when considered in conjunction with the drawing in which, like numeral designations refer to like parts in different figures, and from the appended claims.

In the preferred embodiment, the electromagnetic actuator will be shown as operating a valve for controlling the flow of a fluid through a portal, it being understood nevertheless, that the invention is not so limited, and the actuator may be used in other similar arrangements requiring solenoid type actuation.

In the drawing:

FIGURE 1 is a simplified diagrammatic cross-sectional view, in front elevation, of an electromagnetically actuated valve, embodying the invention and showing the electromagnetic actuator assembled for "noiseless" operation;

FIGURE 2 is a top view on a smaller scale of the electromagnetically actuated valve of FIG. 1;

FIGURE 3 is a simplified schematic diagram of the electrical circuit of the electromagnetic actuator of FIG. 1;

FIGURE 4 is a fragmentary, cross-sectional view of the upper portion of an electromagnetic actuator similar to that of FIG. 1 but modified for "quiet" operation; and

FIGURE 5 is a fragmentary, cross-sectional view similar to that of FIG. 4, showing the electromagnetic actuator of FIG. 1 modified for operation as an impact type.

Referring to FIGS. 1, 2, and 3, in general, the electromagnetic actuator 10 of the valve comprises an energizing coil assembly, generally designated 12, a cylindrical plunger 14 of magnetic material slidably disposed for longitudinal movement in a guide tube 16 of non-magnetic material, and a magnetic frame assembly, generally designated 18, housing coil assembly 12 and tube 16.

The lower end of plunger 14 is provided with a necked down portion 20 to which the upper portion of a valve head 22 is attached by means of pin 24 extending through pin receiving apertures coaxially aligned in plunger portion 20 and valve head 22. Pin 24 is held in place by a retainer ring 26 disposed in peripheral groove 28 formed in valve head 22.

Valve head 22 is provided at its lower end with a circular disc-like portion 30. A resilient valve member 32, such as rubber, is bonded to the bottom surface of valve head portion 30 for sealing engagement with an annular seat 36 interconnecting inlet fluid passageway 38 to outlet passageway 40 defined in valve body 42 to control fluid flow therethrough.

A conical compression spring 46 encircles the lower portion of plunger 14 with one end against the upper surface of valve head 22 and with its other end under compression against the inside surface 50 of an inverted cup-like portion 52 of magnetic frame assembly 18. Spring 46 biases plunger 14 in the position shown in solid outline in FIG. 1, biasing valve head portion 32 against valve seat 36 closing the portal between fluid passageways 38 and 40.

Coil assembly 12 includes a coil 60 wound on a spool 62 and two rectifiers 64, 66 interconnected in the coil energizing circuit as shown in FIG. 3. Coil 60 may be energized from any suitable alternating current source over input leads 68, 70 of the coil circuit. Rectifier 64 is connected between input lead 68 and one end of coil 60 to provide half-wave rectification of the applied alternating current voltage. The second rectifier 66 directly shunts coil 60 with its cathode connected to the junction of the cathode of rectifier 64 with the end of coil 60. Rectifier 66 tends to oppose the decay of the flux field of coil 60, under conditions where the coil is de-energized on the alternate half-cycles of the applied current which are blocked by rectifier 64. Rectifiers 64 and 66 are taped onto spool 62 (FIG. 1) with coil 60; input leads 68, 70 passing through an eyelet 74 provided in frame assembly 18 for connection to an energizing source.

Inverted cup portion 52 of magnetic frame assembly 18 supports a circular washer 78 of magnetic material which is attached thereto, as for example, by means of welding. Guide tube 16 extends through aligned holes defined centrally in member 52 and washer 78, and is provided at its bottom with a turned out rim 16a nesting within cup member 52 and attached thereto. A cap 80 of magnetic material is secured to the upper end of non-magnetic tube 16 by any convenient manner such as by brazing. Cap 80 is bored out, extending the guide tube for plunger 14 beyond the upper end of coil spool 62 and terminating it.

A cover 82 of magnetic material and hollow cylindrical shape closed at the upper end forms part of magnetic frame assembly 18. Cover 82 is of relatively thin walled construction and has defined in its top wall a centrally located hole through which a portion 80a of cap 80 protrudes, when the cover is placed over coil assembly 12. The bottom of cover 82 is formed into an outwardly extending flange 82a which rests over a similar flange 52a of cup member 52. The upper portion 80a of cap 80 is provided with external threads for cooperation with a nut 84 to secure cover 82 in place. Cap 80, cover 82, cup member 52, and washer 78 together comprise magnetic field assembly 18 of electromagnetic actuator

10, providing a predetermined magnetic circuit path for the flux field generated by current flow through coil 60.

With actuator 10 assembled and valve head 22 attached to plunger 14, as shown in FIG. 1, actuator 10 is bolted to valve body 42 by means of fasteners 90 threaded into the valve body; fasteners 90 extending through aligned holes in flanges 52a and 82a. Spring 46 biases valve head 22 into seating engagement with seat 36, preventing fluid flow through the valve.

It may be noted that the lower inner surface of cap 80 is reamed out for a short distance at 85 to receive the upper end of non-magnetic tube 16 and provides a smooth tubular guide surface for plunger 14 into cap 80 at the junction of the tube and cap. Plunger 14 is of length calculated to extend only a certain distance into magnetic cap 80 under conditions where coil 60 is energized. This actuated position of plunger 14 is indicated by the broken-line outline in FIG. 1 of the upper portion 14a of plunger 14 and a part of valve head 22 shown lifted off of valve seat 36. The bottom of plunger 14 in such actuated condition is raised to substantially the level of washer 78. The upper portion 14a of plunger 14 is necked down or stepped to provide a fixed air gap radially between plunger 14 and cap 80. This prevents the occurrence of sufficient residual magnetic attraction between plunger 14 and cap 80 as to interfere appreciably with the return of the plunger to unactuated condition, after coil 60 is de-energized, thereby avoiding what may be termed "magnetic hang-up" of the plunger.

If desired, a portion of plunger 14 may be necked down (not shown) intermediate its ends to minimize its weight. However, the two end portions of plunger 14 must closely follow the interior wall surface of the guide tube for proper guiding and magnetic coupling of the plunger.

Assume that coil 60 is energized through rectifier 64 from an alternating current source connected to leads 68, 70. The flux field generated by current flow through coil 60 each unblocked half-cycle of the applied current is channeled by magnetic frame assembly 18 to magnetically couple plunger 14, actuating it towards its "open valve" position, shown in broken-line outline in FIG. 1. This lifts valve head 22 off seat 36, permitting fluid flow between inlet and outlet passageways 38, 40. Magnetic flux flows through the magnetic path provided by washer 78, cup member 52, cylindrical cover 82, cap 80, across the air gap between cap 80 and the upper end 14a of plunger 14, through plunger 14, and from the bottom end of the plunger across the air gap to washer 78. This magnetic coupling urges plunger 14 upward to a position where the net resultant of the magnetic forces urging plunger 14 upward are balanced by the forces of spring 46 biasing the plunger downward. Plunger 14 comes to a stop at some distance from the closed end of cap 80, as shown in broken-line outline. This balanced position is due to the selection of the plunger length in relation to the position of cap 80 and washer 78. The length is such that the magnetic forces coupling the bottom and top portions of plunger 14 to the magnetic frame assembly 18 are substantially balanced when plunger 14 spans the distance between cap 80 and washer 78; spring 46 being selected with a spring force merely sufficient to return plunger 14 to unactuated position. Plunger 14 is, thus, magnetically balanced in actuated position at some distance from the closed end of its guide tube. This prevents plunger 14 from striking the closed end cap 80, providing actuation of valve 22 without "impact" noise.

Rectifier 66 opposes decay of the flux field of coil 60 during blocked half-cycles of the applied current by providing a current path shunting the coil for current induced in coil 60 by its collapsing flux field. The magnetic forces coupling plunger 14 are, thus, maintained sufficiently during "blocked" half-cycles to maintain plunger 14 in actuated position and to effectively eliminate noise due to A.C. "hum."

As was previously stated, the upper end 14a of plunger

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14 is stepped or necked down to provide a fixed air gap between end cap 80 and the plunger end. This fixed air gap prevents magnetic "hang-up" of plunger 14, when coil 60 is disconnected from its energizing alternating current source.

For applications where some noise may be tolerated but "quiet" operation is desired, the electromagnetic actuator and valve of FIG. 1 may be modified, as shown in FIG. 4 and as follows: The shunting rectifier 66 is omitted from coil assembly 12, only rectifier 64 being provided in the coil circuit. With only this modification, it was discovered experimentally that although plunger 14 is actuated in guide tube 16 toward a magnetically balanced or "null" position without impact against the closed end of cap 80, variations inherent in the half-wave rectified current fed to coil 60 by rectifier 64 tended to oscillate the plunger, producing objectionable A.C. noise or "hum." A washer or shading ring 92 of electrically conductive material, such as copper, and of relatively substantial mass relative to the size of plunger 14 and coil 60 was provided on top of coil 60 encircling cap 80. Copper washer 92 selected in one tested embodiment of a diameter substantially twice that of plunger 14 and of a thickness approximately one-half the radius of plunger 14. Washer 92 need not be circular but may be rectangular. All that is required is that it act as a "shorted turn" providing a shorted current path in which enough current flow is induced by the collapsing of the flux field of coil 60 during blocked half-cycles of the applied current to provide sufficient flux magnetically coupling the upper end 14a of plunger 14 to cap 80 to maintain plunger 14 in its actuated position and minimize A.C. "hum."

If desired, a plunger biasing spring 94 may be disposed in the upper end of the guide tube formed by non-magnetic tube 16 and cap 80, and the conical spring 46, shown in the embodiment of FIG. 1, discarded.

In operation the modified arrangement of FIG. 4 operates similar to that described for the embodiment of FIG. 1; rectifier 64 again acting to rectify the applied alternating current to half-wave direct current. Under such conditions, shading ring or washer 92 functions as a shorted turn providing sufficient flux during blocked half-cycles of the applied power to maintain plunger 14 in its actuated position against oscillation, thereby eliminating the objectionable "hum." This provides "quiet" operation of electromagnetic actuator 10.

For modification of the electromagnetic actuator 10 of FIG. 1 to operation which is neither noiseless nor quiet, a pole assembly 96 (FIG. 5) may be pressed into the inside of cap 80 and both rectifiers 64 and 66 omitted from the coil assembly. Assembly 96 comprises a pole piece 98 of magnetic material dimensioned to engage the upper end surface of plunger 14 when the plunger is actuated to its uppermost position shown in broken-line outline. Encircling pole piece 98 is a small shading ring 100, preferably of copper, in the form of a copper washer. Ring 100 functions as a shorted turn to provide sufficient flux during fluctuations of the magnetic flux field of coil 60 to maintain plunger 14 in its fully actuated position against the end surface of depending pole piece 98. Ring 100 and pole piece 98 are press-fit into an annular retainer 102, which in turn is press-fit into cap 80. In this embodiment the upper portion of plunger 14 is preferably of spherical shape. This construction provides a conventional electromagnetic actuator in which coil 60 is energized directly from an alternating current source, causing actuation of plunger 14 upward against pole piece 98 with impact noise.

In summary, it can be seen that the subject electromagnetic actuators can be readily and economically manufactured from interchangeable parts which provide for ease of assembly and disassembly of actuators for various applications, requiring either noiseless actuators, quiet ones, or where noise is not a factor.

As changes can be made in the above described construction and many apparently different embodiments of

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this invention can be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown on the accompanying drawing be interpreted as illustrated only and not in a limiting sense.

What is claimed:

1. An electromagnetic actuator energizable from an alternating current source, comprising a plunger of magnetic material, a hollow tube of non-magnetic material for slidably receiving said plunger and guiding its movement along the longitudinal axis of said tube, an energizing coil encircling said tube, and a magnetic frame assembly providing a predetermined magnetic path for flux generated by said coil, said assembly including a first member of magnetic material substantially circumventing said tube adjacent one end thereof, a cap of magnetic material closing the other end of said tube, said cap being of hollow cylindrical shape open at one end to extend the tubular guide for said plunger a predetermined distance beyond the adjacent end of said coil, and a second member of magnetic material interconnecting said circumventing member and said cap member to provide a magnetic flux path from said one tube end to said other, the magnetic circuit of which is completed across air gaps at said tube ends to said plunger in said tubular guide causing actuation of said plunger to a certain position under conditions where said coil is energized, said plunger being of such longitudinal dimensions with respect to the longitudinal dimension of said tubular guide such that said plunger when in said certain actuated position extends at least a certain minimum distance beyond said adjacent end of said coil into said cylindrical cap.

2. An actuator as set forth in claim 1 wherein there is provided a spring biasing said plunger against actuation by said energizing coil, said spring exerting a force determined to balance the resultant magnetic force exerted on said plunger by said coil when in said actuated position.

3. An actuator as set forth in claim 2 wherein a pole piece protrudes into said tubular guide from said closed end of said cylindrical cap placing its pole face in position for engagement with the adjacent end face of said plunger when the latter is in its said actuated position, and wherein a shading ring of electrically conductive material encircles said pole piece within said tubular guide for providing sufficient magnetic flux to maintain said plunger actuated during fluctuations of the coil generated field in response to normal cyclical changes of the applied alternating current energizing source.

4. The actuator as set forth in claim 3 wherein said shading ring is in the form of a washer of copper material.

5. The actuator of claim 3 wherein said pole piece and shading ring are constructed for insertion in said cap and retention therein through frictional engagement with adjacent surfaces.

6. An actuator as set forth in claim 2 wherein said second member of said magnetic frame assembly is in the form of a relatively thin walled housing fitting over said coil and tubular guide and is provided with a stud receiving aperture formed coaxially with said cap, and wherein said cap is provided with fastener portion extending through said aperture for removably securing said second member to said tubular guide.

7. The actuator of claim 2 wherein rectifying means are provided at the input of said energizing coil for converting the applied alternating current to half-wave rectified current.

8. An actuator as set forth in claim 7 wherein there is provided a shading ring in the form of a washer encircling said cap and contiguous thereto.

9. The actuator as set forth in claim 8 wherein said washer is of a diameter substantially twice that of said plunger.

10. The actuator of claim 9 wherein said washer is of a thickness at least one-half the radius of said plunger.

11. The actuator of claim 10 wherein said washer is of copper material.

12. The actuator of claim 7 wherein there is provided a shorted turn of electrically conductive material encircling said cap and dimensioned to provide an induced current flow in response to collapsing of the coil generated field during blocked half-cycles of the energizing current, which current flow is of a magnitude and duration to provide at least sufficient magnetic coupling of said plunger end cap to eliminate effectively A.C. noise and maintain the plunger in actuated position.

13. The actuator set forth in claim 2 wherein said biasing spring is a coil type spring disposed in said tubular guide between said closed end of said cap and said plunger.

14. The actuator set forth in claim 7 wherein there is provided a rectifier directly shunting said coil providing

a path for current generated in said coil by collapsing of said coil flux field during blocked alternate half-cycles of the applied current source, which cycles are blocked by said half-wave rectifying means.

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15 MILTON O. HIRSHFIELD, *Primary Examiner*.

J. A. SILVERMAN, *Assistant Examiner*.