ELECTRO-MAGNETIC ACTUATOR WITH ARMATURE ASSEMBLY
SLIDABLE BETWEEN TWO LIMIT POSITIONS
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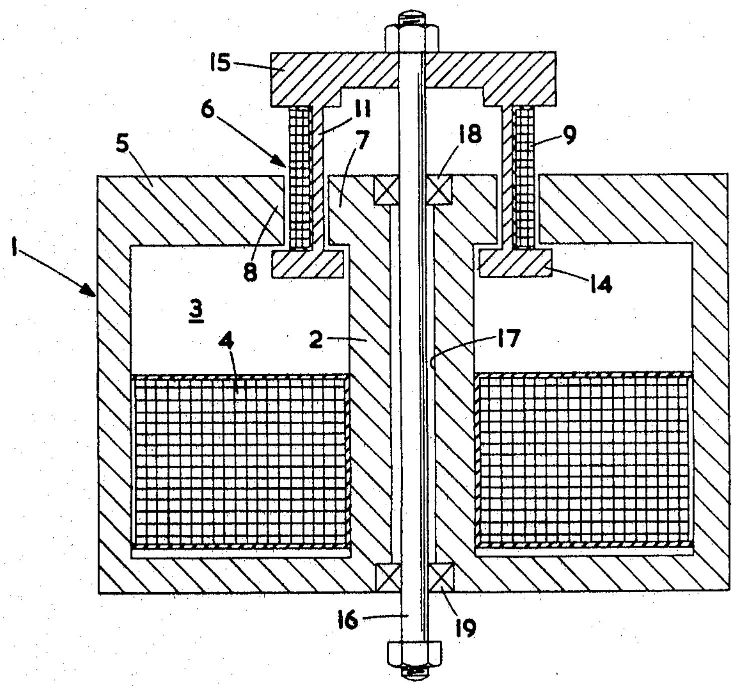

FIG. 1

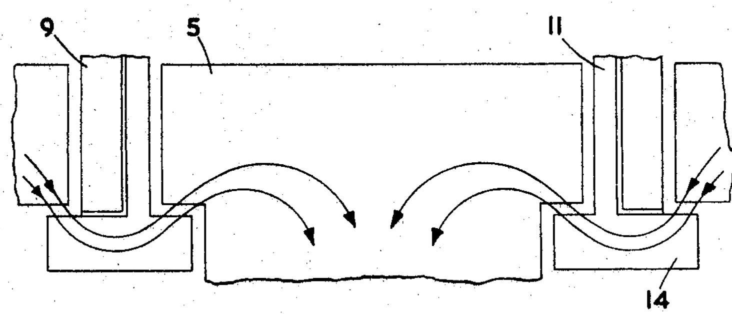

FIG. 2A

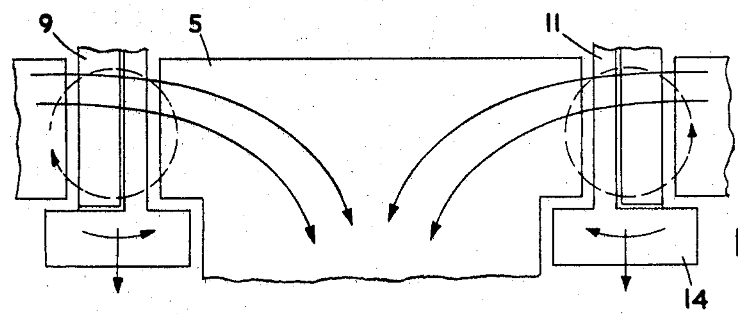

FIG. 2B

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# ELECTRO-MAGNETIC ACTUATOR WITH ARMATURE ASSEMBLY SLIDABLE BETWEEN TWO LIMIT POSITIONS

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## ABSTRACT OF THE DISCLOSURE

An electro-magnetic actuator has an armature assembly which is suitable for actuated travel distances of the order of 1 inch, and which comprises a flux-diverting coil wound upon a cylindrical former, the latter carrying latching poles at each of its ends. The armature assembly is slidably mounted via a rod in a central shaft of a cylindrical casing and the flux-diverting coil is disposed within an annular air gap formed in one end wall of the casing. An electromagnet is contained within the casing for providing a radial magnetic flux path across the air gap. The armature assembly is slidable between two limit positions which are each defined by the respective latching pole bridging the air gap and latching the armature assembly to the casing, the main flux path being diverted through the bridging latching pole. Energisation of the flux-diverting coil with a suitable D.C. pulse, when the armature is in one of its limit positions, produces magnetic flux which opposes the diverted main flux path through the bridging pole to unlatch it from the casing and which reacts with the main flux path in the air gap to produce a thrust urging the armature assembly towards the other limit position.

This invention relates to electro-magnetic actuators.

It is well-known to provide electro-magnetic actuators having an armature which is movable between two latched limit positions. In such actuators there is provided a permanent or electro-magnet and flux-diverting coils, the armature movement being effected by appropriately energising the coils. By such arrangements armature movements of up to, say, 0.3 inches have been attained.

The actuators are particularly useful for controlling the operation of electric switches by mounting the movable contacts thereof on the armature. While such arrangements have previously been satisfactory, it has been found that there now exists a requirement, especially when controlling the operation of electric switches of the vacuum interrupter type, to provide actuators whose armatures are movable through distances of the order of 1 inch. This is to enable greater separation distances to be provided between the fixed and movable contacts of the switches and also to increase the length of contact "wipe" between the fixed and movable contacts of the switches.

By contact "wipe" we mean the amount by which the length of movement of the armature exceeds the separation distance of the contacts. Contact "wipe" is taken up during a closing operation by a compression spring which is compressed so as to apply a contact pressure to the contacts.

According to this invention, an electro-magnetic actuator includes a body having two portions which define an air gap between them, magnetic flux producing means for providing a main flux path through the body and across the air gap, an armature assembly comprising a flux-diverting coil and a latching pole piece, the armature assembly being movable into or out of a limit position in which said coil lies within the air gap, said pole piece bridges the air gap and the main flux path across the air gap is diverted through said pole piece so that the armature assembly is latched to the body, the arrangement being such that said coil surrounds one of the body portions and moves through said air gap during such movement and, when the armature assembly is latched in the limit position, energisation of said coil with a current of suitable polarity produces flux which flows through said pole piece in opposition to the main flux so as to unlatch the pole piece and links with the main flux to provide a thrust which urges the armature assembly out of the limit position.



Preferably the armature assembly has another latching pole piece spaced from said pole piece and is movable from said limit position to another limit position in which the other pole piece bridges the air gap and in which the main flux path across the air gap is diverted through the other pole piece so that the armature assembly is latched to the body in the other limit position, the arrangement being such that said armature assembly is unlatched from each limit position and moved between the limit positions by the appropriate energisation of said coil.

Conveniently the air gap provided by the body portion is annular and the flux-diverting coil is wound on to a cylindrical former which may readily carry a latching pole piece at each of its ends.

In order that the invention may be readily understood, an electro-magnetic actuator constructed in accordance with the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 is a sectional side elevation of the actuator and FIGS. 2A and 2B are a series of diagrams showing the operation of the actuator.

Referring to FIG. 1 of the drawings, the actuator comprises a cylindrical casing **1** of magnetic material having a central shaft **2** of circular cross-section formed integrally therewith, the casing and shaft thus providing between them an annular space **3** which houses an annular electro-magnetic holding coil **4**. One end wall **5** of the casing **1** is provided with an annular air gap **6** which opens into the space **3** and the central and outer portions reference **7** and **8** of said end wall provide inner and outer poles respectively for the air gap.

An armature assembly comprises a flux-diverting or drive coil **9** wound on to a cylindrical former **11**, which latter connects a pair of spaced coaxial latching poles **14** and **15**. The armature assembly is connected via its latching pole **15** to a rod **16** which extends through an axial bore **17** in the shaft **2** of the casing **1**, and the rod is slidably mounted in bearings **18** and **19** located in counterbores at each end of said axial bore; either end of the rod **16** may be connected by any suitable coupling means to the mechanism with which the actuator is to be used, e.g. the movable contact of a vacuum interrupter switch. The armature assembly is disposed with its coil **9** carried by the former **11** within said annular air gap and surrounding the central wall portion **7** and with the latching pole **14**, which is of annular form, disposed within the casing **1**, and the latching pole **15**, which is of circular form, outside the casing. The armature assembly is thus axially slidable with respect to the air gap **6** between two limit positions defined by the latching poles abridging the air gap and engaging their respective faces of the end wall **5**. The former **11** and latching poles **14**, **15** may be of integral construction and may, for example, be turned from solid mild steel for strength. Alternatively, the former may be of non-magnetic material, e.g. non-magnetic stainless steel, and have the latching poles, made from a suitable magnetic steel, welded thereto. In either case, to facilitate insertion of the armature assembly in the air gap **6**, the poles **7** and **8** and latching poles **14** and **15** may be slotted. This of course will also provide the advantage of reducing eddy currents.

In operation of the actuator, the armature assembly is required to be moved between its two limit positions and to be latched to the body of the actuator in these positions. This is achieved by energizing the holding coil **4** which produces a strong radial magnetic flux through the pole pieces **7** and **8** and across the annular air gap **6**, and by applying D.C. pulses of suitable polarity to the drive coil **9** of the armature assembly.

Thus referring to FIG. 2A of the drawings, the assembly is shown in one of its limit positions in which the latching pole **14** is latched against its respective face of the end wall **5** and it will be seen that the main flux lines are distorted from the air gap **6** to pass via said latching pole, thus holding the latter clamped against its face. If now it is required to move the assembly to its other limit position, a D.C. pulse of suitable polarity is applied to the drive coil **9** such that a flux is produced in the latching pole **14** which opposes the main flux. This causes the main flux to be reduced in density at that face of the end wall which is engaged by the latching pole **14**, and to be diverted towards the other face of the end wall as shown in FIG. 2B. In addition, the magnetic coupling between the flux produced by the drive coil **19** and the main flux is such as to provide a thrust to the armature assembly inwardly towards the casing **1**, and therefore the assembly is urged towards its other limit position. As the latching pole **15** approaches the face of the end wall **5**, a fringe or leakage flux is present between the end wall **5** and the latching pole **15** adding to the thrust due to energisation of the drive coil **9** until the latching pole **15** reaches its other limit position with the latching pole **15** engaging its respective face of the end wall **5**. The main flux then distorts through the latching pole **15** resulting in a latching action similar to that shown in FIG. 2A.

It will be appreciated that if a further D.C. pulse of opposite polarity is now applied to the drive coil **9**, the armature assembly will be unlatched and returned to and latched in its initial limit position as shown in FIG. 2A in a similar manner to that described hereinbefore.

An expermental actuator has been constructed and has operated as described above. It was observed that operation was considerably slower when the actuator was operating with the drive coil **9** moving out of the casing of the actuator. This is due to the normally ineffective half of the turns of the drive coil winding which is outside the annular opening **6**, acting like a solenoid on the centre pole of the electro-magnetic holding coil **4** and opposing the force of the drive coil turns which are in the opening.

This means that the operating speed of the assembly is slower moving outwards than inwards when the actuator is unloaded, but this effect can be of advantage in vacuum interrupter switch applications where it is often better to close slowly and open fast. If the inward movement of the assembly is used to close the switch and the outward movement is used to open it, the switch contact pressure will then be acting in the direction aiding the actuator in its slower direction and travel times can be made nearer equal.

The experimental model has rating as follows:

Weight—62 lbs.
Holding coil watts—45
Holding force—1250 lbs.
Travel distance—1.25 in.
Drive coil resistance—12 ohms
Drive coil current—25A D.C. pulse
Total operating time—Downwards against 360 lbs. spring over ⅞ in. 25 ms. Upwards with 360 lbs. spring aiding 13 ms.

Various modifications may be made within the scope of the invention. For example, the electro-magnetic holding coil **4** may be replaced by a permanent magnet if a no-volt facility is not required and if the level of the holding force is not important.



The holding force may be reduced by fitting non-magnetic shims between the latching poles **14**, **15** and their respective faces of the end wall **5** while retaining high speed of operation and high thrust during the stroke.

Also the armature assembly could be mounted on other suitable types of slidable mountings to give added sideways rigidity.

It will be appreciated that it is not necessary for the actuator casing **1** to be cylindrical. For example, it could be square, thus allowing the drive coil **9** to be square and the armature assembly to be movable on simple hinges.

I claim:

**1.** An electro-magnetic actuator including a magnetic body having two portions which define an air gap between them; magnetic flux producing means magnetically coupled to said body portions so as to provide a main flux through said body portions and across said air gap; and a movable armature assembly comprising a latching pole piece and a flux-diverting coil which surrounds one of the body portions and moves through said air gap during movement of said movable armature assembly, movement of said movable armature assembly being limited by a limit position in which said latching pole piece bridges said air gap and the main flux across said air gap is diverted through said latching pole piece so that said movable armature assembly is latched to said body; said flux-diverting coil being such as, when energized with a current of suitable polarity while said movable armature assembly is latched in said limit position, to produce magnetic flux which flows through said latching pole piece in opposition to the main flux so as to unlatch said latching pole piece and which links with the main flux to provide a thrust which urges said movable armature assembly out of said limit position.

**2.** An electro-magnetic actuator according to claim **1**, wherein said movable armature assembly includes another latching pole piece spaced from the first-mentioned latching pole piece and is movable from said limit position to another limit position in which the other latching pole piece bridges said air gap and in which the main flux across said air gap is diverted through said other latching pole piece so that said movable armature assembly is latched to said body in the other limit position, the arrangement being such that said movable armature assembly is unlatched from each limit position and moved between the two limit positions by appropriate polarity energization of said flux-diverting coil.

**3.** An electro-magnetic actuator according to claim **2**, wherein said movable armature assembly includes a cylindrical former which interconnects the two latching pole pieces and surrounds said one of the body portions, said flux-diverting coil being wound onto said cylindrical former.

**4.** An electro-magnetic actuator according to claim **3**, wherein said cylindrical former and the two latching pole pieces are of integral construction.

**5.** An electro-magnetic actuator according to claim **3**, wherein said cylindrical former is formed of a non-magnetic material.

**6.** An electro-magnetic actuator according to claim **1**, wherein said magnetic flux producing means comprising an electro-magnetic coil surrounding part of said body so as to provide said flux.

**7.** An electro-magnetic actuator according to claim **1**, wherein said air gap is annular being defined between a central one of said body portions and an outer one of said body portions, said flux-diverting coil surrounding said central body portion.

**8.** An electro-magnetic actuator according to claim **7**, wherein said movable armature assembly is secured to an actuating rod, means define a bore in said central body poriton, and bearing means carried by said body support said actuating rod for sliding movement within said bore.

9. An electro-magnetic actuator according to claim 7, wherein slidable mounting means external of said body supports said movable armature assembly for sliding movement.

10. An electro-magentic actuator including a magnetic body having two portions which define an air gap between them; magnetic flux producing means magnetically coupled to said body portions so as to provide a main flux through said body portions and across said air gap; and an armature assembly comprising a flux-diverting coil and a pair of latching pole pieces which are spaced apart by said flux-diverting coil, said armature assembly being movable between two limit positions defined by a respective pole piece bridging said air gap so that the main flux path across said air gap is diverted through said respective pole piece to latch said armature assembly to said body, said flux-diverting coil surrounding one of the body portions so as to move through said air gap during movement of said armature assembly; and said flux-diverting coil being such as, when energized with a current of suitable polarity while said armature assembly is latched in a said limit position, to produce magnetic flux which flows through said respective latching pole piece in opposition to the main flux so as to unlatch said respective latching pole piece and which links with the main flux to provide a thrust which urges said armature assembly towards the other limit position.



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GEORGE HARRIS, Primary Examiner

U.S. Cl. X.R.

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