

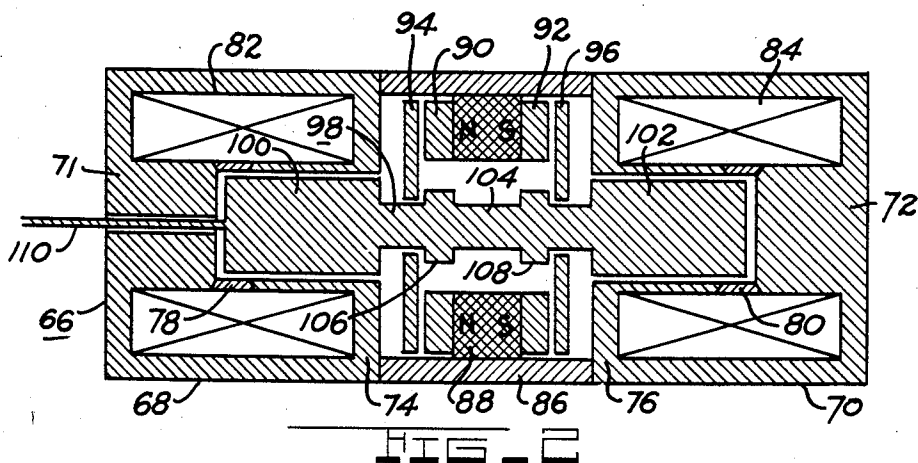
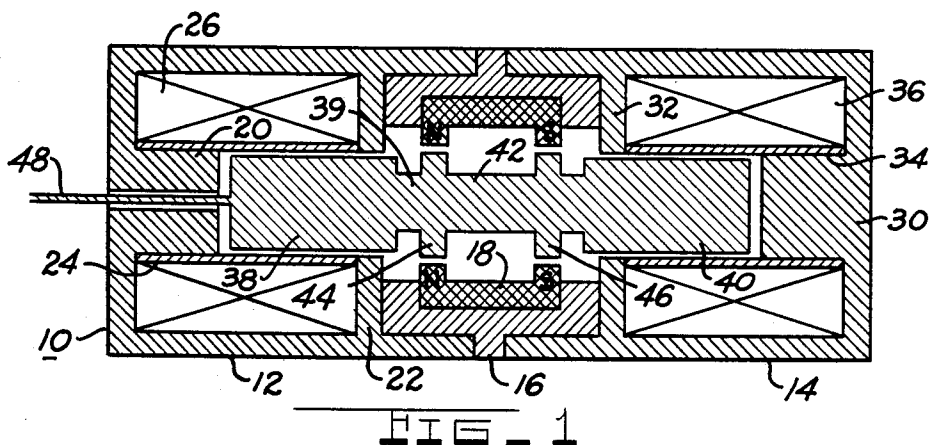
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THREE-POSITION LATCHING SOLENOID ACTUATOR

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-  COIL.
-  PERMANENT MAGNET MATERIAL.
-  MAGNET MATERIAL.
-  NON MAGNETIC MATERIAL.

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3,070,730 THREE-POSITION LATCHING SOLENOID ACTUATOR

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This invention relates to solenoid actuators and more particularly to an actuator capable of providing three possible axial positions on an output shaft.

A three position solenoid controlled actuating device has a number of possible applications. Recently it has been desired to use a device of this kind to control the position of vanes or fins for missile applications wherein such vanes or fins can be operated in a centered position plus two other positions. Devices of this nature are also useful as three position electrical switching devices. Where the output shaft is attached to a spool valve a combination of flow patterns for a servo-mechanism or a gear shifting mechanism may be provided. Certain problems are encountered in attempting to provide a mechanism of this nature such as assuring that the magnetic circuits are as efficient as possible, that the output shaft will be precisely located at all of the possible positions, and that the design be such that the permanent magnet is not damaged or deteriorated either through excessive physical movement or through being subjected to demagnetizing flux from the solenoids. It is therefore an object of the present invention to provide a three position solenoid actuated device in which the physical size of the components may be at a minimum because of the high efficiency of the magnetic circuit.

It is another object of the present invention to provide a three position solenoid actuated device in which a permanent magnet is provided to control one of said positions and in which said permanent magnet is never subjected to demagnetizing flux from the associated solenoid windings.

It is another object of the present invention to provide a three position solenoid actuator in which a permanent magnet is used to control the output shaft to one of said positions and in which there is no physical movement of or contact with the permanent magnet.

It is a further object of the present invention to provide a three position solenoid actuator device in which the output shaft is precisely located in each of its three positions.

Other objects and advantages will become apparent from the following specification taken in connection with the accompanying drawings in which:

FIGURE 1 is a sectional view of one modification of our three position solenoid actuator; and

FIGURE 2 is another modification of our three position solenoid actuator.

Referring now to FIGURE 1, our actuator includes a housing shown generally at 10 which includes two cup-shaped magnetic members 12 and 14. Positioned between members 12 and 14 is a non-magnetic section 16 which serves to magnetically isolate members 12 and 14 from each other and also to magnetically isolate and physically locate an annular permanent magnet member 18 within its interior. Member 12 includes a pole piece section 20 and an annular section 22. Positioned within member 12 is an annular non-magnetic coil form member 24 upon which is wound a coil 26. Similarly member 14 includes a pole piece 30, an annular section 32 and contains a cylindrical non-magnetic coil form member 34 upon which is wound a coil 36. Reciprocating within the hollow interiors of coil form members 24 and 34 are armature sections or lands 38 and 40 respectively

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forming part of armature 39 and which are connected by means of a small diameter section 42 carrying additional lands 44 and 46 which cooperate with the permanent magnet 18 to close the magnetic circuit receiving its energy from the permanent magnet 18. Attached to the left end of armature section 38 is a control output shaft 48.

As shown, the device of FIGURE 1 appears in its centered position and it will be observed that a substantial air gap appears between pole piece 20 and armature section 38 and also between pole piece 30 and armature section 40. The coils 26 and 36 are not energized and the armature is held in this centered position through the action of the permanent magnet 18 which, being magnetized axially, and having a U-shaped cross section, as shown, exerts a magnetic force tending to cause lands 44 and 46 to be directly aligned with its poles. Inasmuch as there is no other force acting on the armature 39, it is held in the centered position and the output shaft 48 is in its intermediate position. When winding 26 is energized lines of magnetic force are concentrated in the member 12 including the pole piece 20 and the annular section 22 and these also flow through the armature section 38 and cause a substantial force tending to close the air gap existing between pole piece 20 and armature section 38. This force substantially exceeds that exerted by the permanent magnet 18 and the entire armature section 39 is moved to the left carrying shaft 48 which is moved to its extreme left position. Similarly, when coil 26 is de-energized and coil 36 is energized lines of force flow around member 14, and across pole piece 30 and armature 40 thus exerting a force tending to close the air gap between armature section 40 and pole piece 30. This force being sufficient to overcome the force of the permanent magnet 18, the entire armature 39 is moved to the right and the output shaft 48 is therefore located in its extreme right position. It will be observed that the non-magnetic housing section 16 extends to the exterior of the housing 10, thereby completely separating the magnetic members 12 and 14 and therefore isolating their magnetic circuits from each other. It also isolates the permanent magnet member 18 from the adjacent annular sections 22 and 32 so that the permanent magnet 18 is never subjected to a demagnetizing flux when the coils 26 and 36 are energized. The coil form members 24 and 34 are non-magnetic so that the lines of force created by the energization of coils 26 and 36 will not be short circuited through the coil form member and will be forced through the armature sections 38 and 40. Applicants have not attempted to show the manner in which members such as 12, 14 and 16 may be disassembled, this being considered a matter of mechanical detail which could change with the particular application for which the solenoid device was employed and modifications of this nature are therefore believed to be well within the skill of the art.

In the device of FIGURE 2 a modification is shown which includes the advantage that the permanent magnet is effectively isolated from demagnetizing flux, it is not subjected to any physical movement as a result of movement of the armature, and yet positive mechanical stop means are provided for establishing and maintaining the centered position of the output shaft. In this configuration the housing shown generally at numeral 66 includes a cylindrical container section 68 on one end and a similar section 70 on the opposite end including pole pieces 71 and 72 and annular coil form members 74 and 76, respectively. A non-magnetic insert 78 is shown positioned between pole piece 71 and coil form member 74 and a similar insert 80 is shown positioned between pole piece 72 and coil form member 76. Contained within member 68 is a winding 82 and contained within member 70 is a winding 84. The non-magnetic

inserts 78 and 80 serve the same purpose as the non-magnetic coil form members 24 and 34 shown in the FIGURE 1 modification in that they cause the magnetic lines of force produced upon energizing of windings 82 and 84 to flow across the air gap at the end of the armature sections rather than permitting them to be short-circuited along the coil form members. Also forming part of housing 66 is a cylindrical section of non-magnetic material 86 containing an annular permanent magnet 88. Positioned on each side of the permanent magnet member 88 are annular members 90 and 92 of magnetic material and positioned adjacent these members are additional annular members or floating disks 94 and 96 which have a much smaller inside diameter. The armature 98 in this case is made entirely of magnetic material and includes a section or land 100 adapted to abut against pole piece 71 and another section or land 102 adapted to abut against pole piece 72. It also includes a small diameter section 104 carrying a pair of smaller lands 106 and 108.

When the coils 82 and 84 are de-energized the permanent magnet 88 exerts a force pulling the floating disks 94 and 96 toward the center against the members 90 and 92 thereby carrying the lands 106 and 108 toward a centered position and maintaining the armature 98 in its centered position. When the winding 92 is energized the armature section 100 is pulled against the pole piece 71 thereby pulling the entire armature 98 and the output shaft 110 to the left. The small land 106 then engages the floating disk 94 and pulls it away from the face of the annular member 90 and a rather substantial air gap is opened in the magnetic path between member 90 and floating disk 94. When coil 82 is de-energized and coil 84 is energized the air gap is closed between armature section 102 and pole piece 72 thus moving the armature 98 and the output shaft 110 to its extreme right position. Under these conditions the land 106 will move to the right and the floating disk 94 will be pulled to the right against member 90 through the action of the permanent magnet 88 but the land 108 will pull the disk 96 away from the face of member 92 thereby opening a substantial air gap in the magnetic path between floating disk 96 and the member 92. The annular members 90 and 92 serve to cushion the impact of the floating disks 94 and 96 against the permanent magnet 88 when the armature 98 is moved. The device would be entirely operative if the permanent magnet were simply expanded in size to include the volume of annular members 90 and 92; however, the material in the permanent magnet member 88 is normally quite brittle and longer life of the magnet will be obtained if it is protected as shown.

While only two embodiments have been shown and described herein modifications may be made to suit the requirements of any particular application without departing from the scope and spirit of the invention.

We claim:

1. A device for controlling the axial position of a control shaft comprising first and second housing members of magnetic material having a hollow substantially cylindrical interior and a pole piece at one end, a cylindrical coil form member of non-magnetic material in each of said housing members, a coil positioned in each of said housing members and wound on each of said coil form members, a third housing member of non-magnetic material positioned to separate said first and second members, a hollow permanent magnet member positioned within said third housing member and magnetically isolated from said first and second housing members, and an axially movable member of magnetic material attached to said control shaft including first and second armature sections slidable within each of said coil form members, and a third armature section positioned to complete a magnetic circuit with said permanent magnet such that when either of said coils is energized said movable mem-

ber is moved against its corresponding pole piece and when neither coil is energized said third armature section and said permanent magnet cooperate to hold said movable member in a centered position between said pole pieces.

2. A device for controlling the axial position of a control shaft comprising first and second magnetic housing members having a hollow substantially cylindrical interior and a pole piece at one end thereof, a cylindrical coil form member of non-magnetic material positioned in each of said first and second magnetic housing members, a coil wound on each of said non-magnetic coil form members and positioned within the interior of said housing members, a hollow member of non-magnetic material positioned between said first and second housing members, a hollow permanent magnet positioned within said last named member and magnetically insulated from said housing members, an axially movable member of magnetic material attached to said control shaft including first and second armature sections slidable within said non-magnetic coil form members, and a third armature section positioned to complete a magnetic circuit with said permanent magnet such that when either of said coils is energized said movable member is moved against its corresponding pole piece and when neither coil is energized said third armature section and said permanent magnet cooperate to hold said movable member in a centered position between said pole pieces.

3. A device for controlling the axial position of a control shaft comprising first and second magnetic housing members, having a hollow interior and a pole piece at one end thereof, a cylindrical coil form member of non-magnetic material positioned in each of said housing members, a coil wound on each of said coil form members within the interior of each of said housing members, a hollow member of non-magnetic material positioned between each of said housing members, permanent magnet means located between said magnetic housing members, an axially movable member attached to said control shaft including first and second armature sections of magnetic material slidable within each of said non-magnetic coil form members, and a third armature section positioned relative to said permanent magnet means such that when either of said coils is energized said movable member is moved against its corresponding pole piece and when neither coil is energized said third armature section and said permanent magnet means cooperate to hold said movable member in a centered position between said pole pieces.

4. A solenoid device capable of locating an output shaft in any of three desired axial positions comprising an armature member having a plurality of lands attached to said shaft, a pair of cylindrical coil form members at least partly of non-magnetic material within which the land on each end of said armature reciprocates, a coil wound on each of said coil form members, a housing for said device including a pair of pole pieces of magnetic material against which each of said end lands may abut and a pair of cylindrical container sections enclosing said coils, a permanent magnet arranged to complete a magnetic circuit through two other of said lands, and an insert of non-magnetic material arranged to magnetically isolate said permanent magnet from said container sections and said container sections from each other, whereby energizing of one coil causes said armature to be moved against one of said pole pieces, energizing of the other coil causes said armature to be moved against the other of said pole pieces, and de-energizing of both coils causes said two other lands to be aligned axially with said permanent magnet.

5. A solenoid device capable of locating an output shaft in any of three desired axial positions comprising an armature member having a plurality of lands attached to said shaft, a pair of cylindrical coil form members at

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least partly of non-magnetic material within which the land on each end of said armature reciprocates, a coil wound on each of said coil form members, and a cylindrical section of non-magnetic material magnetically isolating said container sections from each other; an annular permanent magnet positioned within said cylindrical section, a pair of annular members of magnetic material positioned within said cylindrical section on either side of said magnet arranged to slide on the small diameter sections of said armature and against two inside lands of said armature to complete a magnetic circuit from said magnet to said armature, whereby energizing one of said coils causes said armature to be moved against one of said pole pieces thereby opening an air gap between one of said annular members and said magnet, energizing of the other of said coils causes said armature to be moved against the other of said pole pieces thereby opening an air gap between the other of said annular members and said magnet, and de-energizing of both coils causes said annular members to be moved toward said permanent magnet thus positioning said armature between said pole pieces.

6. A solenoid device capable of locating an output shaft in any of three desired axial positions comprising an armature member having a plurality of lands attached to said shaft, a pair of cylindrical coil form members at least partly of non-magnetic material within which the lands on each end of said armature reciprocate, a coil wound on each of said coil form members, a housing for said device including a pair of pole pieces against which of each of said end lands may abut and a pair of cylindrical container sections enclosing said coils, permanent magnet means arranged to cooperate with at least one other of said lands to produce a force tending to hold said armature in a position between said pole pieces, a non-magnetic

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member adjacent said permanent magnet for magnetically isolating from each other the magnetic circuits produced upon energization of said coils, whereby energizing of one coil causes said armature to be moved against one of said pole pieces, energizing of the other coil causes said armature to be moved against the other of said pole pieces, and de-energizing of both coils permits said armature to be positioned by said permanent magnet means.

7. A device for locating a control shaft in any of a plurality of desired positions comprising a plurality of magnetic housing members having a hollow interior, a cylindrical coil form member of non-magnetic material positioned within each of said housing members, a coil wound on each of said coil form members, at least one member of non-magnetic material positioned to magnetically isolate said housing members from each other, permanent magnet means located coaxially with said housing members, and an axially movable member attached to said control shaft including an armature section for each of said coils and one armature section arranged to complete a magnetic circuit with said permanent magnet means, whereby when any of said coils is energized said movable member is axially positioned by the corresponding armature section being moved to minimize the effective air gap in its particular magnetic circuit, and when none of said coils is energized said movable member is axially positioned by said one armature section being moved to minimize the effective air gap in the magnetic circuit including said permanent magnet means.

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