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DUAL POSITION LATCHING SOLENOID

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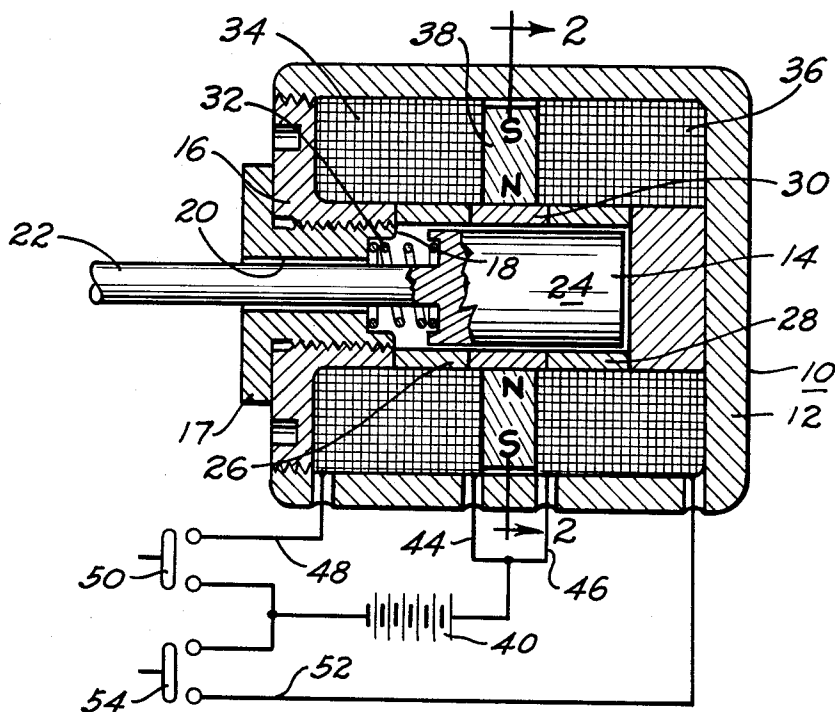


FIG. 1

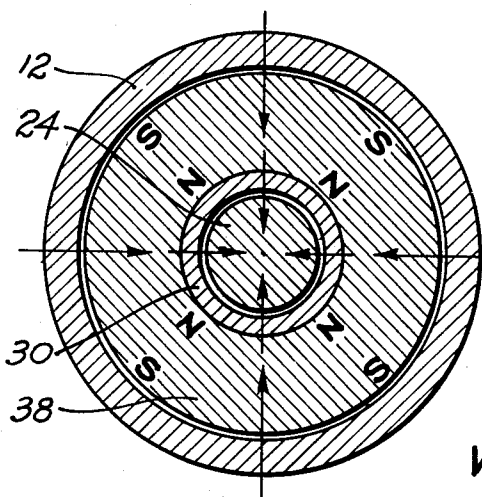


FIG. 2

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## DUAL POSITION LATCHING SOLENOID

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This invention relates to solenoids and more particularly to a unique design for a dual position latching solenoid having special utility as a valve actuating means in high pressure fluid control systems.

In certain control systems presently in use, a great premium is placed on solenoid designs possessing the combination of lightweight, simple and durable construction and highly reliable operation. In the case of solenoids having the feature of latching at each end of their travel, one or more permanent magnets are customarily used to provide the residual magnetism necessary to hold the armature in the position last called for by the electro-magnet structure. Where one magnet is used it has been difficult to arrange the structure such that the permanent magnet is never subjected to demagnetizing forces on one cycle or the other of the operation. It is, therefore, an object of the present invention to provide a dual position latching solenoid having one permanent magnet member which is never subjected to magnetomotive forces tending to demagnetize it.

It is another object of the present invention to provide a dual position latching solenoid which is highly reliable in operation and which will provide a maximum force output for a given physical size.

It is another object of the present invention to provide a dual position latching solenoid which accomplishes the above objects and which is simple in design and easily fabricated.

It is another object of the present invention to provide a dual position latching solenoid which accomplishes the above objects and which is constructed to provide a positive seal protecting the windings from high fluid pressures existing in the chamber containing the armature.

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

FIGURE 1 is a cross-sectional view of a solenoid device embodying my invention shown in conjunction with a schematic actuating circuit; and

FIGURE 2 is a sectional drawing of the device of FIGURE 1 taken on line 2-2 thereof.

Referring to FIGURE 1, the housing 10 consists of a cylindrical cup-shaped member of magnetic material 12 and a member 16 threadedly engaged with member 12 which partially closes the opposite end of the housing and acts as a coil form member. Member 16 also includes a pole portion 14. A cap screw 17 threadedly engaged with member 16 contains a pole portion 18. A bore 20, drilled through member 17, receives a shaft 22 attached to a cylindrical armature member 24. Shaft 22 may be attached to a valve or any desired control member.

A light spring 32 is shown positioned between armature 24 and pole portion 18 providing a biasing force tending to move said armature to the right. The use of this spring is optional, depending upon requirements. It could be positioned to bias the armature the other way or eliminated entirely if balanced action is desired.

Armature 24 is adapted to reciprocate in a cylindrical structure consisting of a pair of non-magnetic portions 26 and 28 and a magnetic portion 30. This entire assembly may consist of separate pieces, but where high fluid pressure may force fluid along shaft 22 into the chamber occupied by armature 24, it is fashioned integral with member 16 so that the chamber formed on the

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interior thereof is fluid-tight. One manner in which such a structure has been made is by forming member 16 as a solid cylindrical piece of magnetic material having a flange as shown. Grooves are then cut in the outside of this cylinder and filled with welding rod of non-magnetic stainless steel. The internal diameter is then drilled out to the desired size thus removing all of the magnetic material on the inside of said non-magnetic stainless steel. The outside of the cylinder is then machined to the desired diameter.

A pair of coils or windings 34 and 36 are positioned as shown with respect to the members 12 and 16 (including portions 26, 28 and 30) which act as both housing and as coil form members. Positioned between coils 34 and 36 is an annular, radially magnetized permanent magnet which is also positioned concentrically with respect to armature 24 and magnetic member or portion 30 (see FIGURE 2). This magnet is magnetized as shown with the result that lines of flux flowing there-through are in the direction indicated by the arrows of FIGURE 2. The clearance between members 24 and 30 are exaggerated to show the separate parts. Actually, it is desired that this air gap be kept to a minimum. The air gap between members 38 and 12 is useful to control the amount of flux available across the air gaps to thereby control the latching force.

The energizing circuit for the coils 34 and 36 is shown on FIGURE 1 and consists of a battery 40 (or which may be any equivalent voltage source) having a positive terminal connected to the inside wires 44 and 46 of each of said coils. The negative terminal may be connected to the outside wire 48 of winding 34 by closing a switch 50 which results in energizing winding 34 or it may be connected with the outside wire 52 of winding 36 by closing a switch 54 thus energizing said winding 36.

As shown, the armature 24 is held against the pole piece 14 through the action of the biasing spring 32 and the magnetomotive force resulting from the action of the permanent magnet 38. The action of the biasing spring is believed obvious and its effect on the operation of the solenoid will hereinafter be ignored. Actually there are two magnetic paths produced by the magnet 38, the first path flowing from outside to inside of the magnet, through member 30, armature 24, pole portion 14 and housing 12 around to the outside of the magnet; and the second path flowing in the same direction through the magnet and member 30, toward the left end of armature 24, across the air gap between the armature and pole portion 18, through members 16 and 12 back to the outside of the magnet. The greatly increased air gap on the left end of the armature, of course, means that the reluctance of the second path is much greater than that of the first and there is much less force tending to move the armature to the left than there is tending to move it to the right. The non-magnetic members 26 and 28 serve to prevent the flux from by-passing the armature 24.

Closing the switch 50 causes coil or winding 34 to be energized and a considerable increase in flux density in the second path results. At the same time flux is produced which flows around the outside of coil 36 and passes across the closed air gap on the right end of armature 24, thereby bucking out the flux from the permanent magnet 38. The flux from the permanent magnet is redirected across the air gap on the left end of the armature. The flux across the closed air gap is then reduced to zero or a very low value at the same time that it is increased substantially across the open air gap. The resulting force moves the armature to its left extreme of travel. Even if the flux across the closed air gap is actually reversed in direction, this same excess flux is also effective, to some extent, across the open air

gap, thus leaving the net difference in flux across the two ends of the armature approximately the same. After the armature 24 has moved to the left extreme of travel, and the switch 50 is opened, thereby de-energizing coil 34, the armature is held in this position by the residual inductive flux of the permanent magnet in the same manner as it was originally held in the right hand position.

Closing of switch 54 will then energize coil 36 producing lines of flux substantially aiding those produced by the permanent magnet 38 in the first path described above and also producing a flow of flux around the outside of coil 34 and opposing the flux from the permanent magnet which flows across the left air gap. This results in movement of the armature to its extreme right hand position of travel. Opening of switch 54 will de-energize coil 36 but the armature 24 will remain in the right hand position because of the residual inductive flux of the permanent magnet, as previously set forth. It will be observed that although the flux produced by the permanent magnet 38 is bucked out across one or the other of the air gaps when a switching operation occurs, this never results in the production of flux opposing that of the permanent magnet across the magnet itself. On the contrary, the inductive flux produced by energization of the windings 34 and 36 always results in a flow across the permanent magnet 38 which is tending to further magnetize said permanent magnet.

Although only one form of the invention is shown and described herein, it is recognized that modifications may be made to suit the requirements of particular applications.

I claim:

1. A solenoid device comprising a substantially cylindrical housing of magnetic material having a pair of pole faces positioned along the axis thereof, a cylindrical armature member positioned along said axis and adapted to move linearly between said pole faces, a unitary cylindrical structure sealed at one end forming part of said housing within which said armature reciprocates having inserts of non-magnetic material positioned adjacent each end of said armature for blocking a flux path tending to flow axially through said cylindrical member, a coil of wire positioned adjacent each end of said armature within said housing and concentric with respect to said cylindrical member, an annular, radially magnetized permanent magnet positioned in said housing between said coils of wire and concentrically with respect to said armature, the polarization of said coils being such that the magnetic lines of force produced upon energization of either of said coils of wire always tends to further magnetize said permanent magnet, whereby upon energization of either of said coils of wire said armature is moved in a direction to abut against the pole piece nearest said coil, and upon subsequent de-energizing of said coils of wire said armature is held in position against said pole piece by the magnetic force produced by said permanent magnet.

2. A solenoid device comprising a housing of magnetic material having a pair of pole faces positioned at each end thereof, a pair of annular coil members positioned along a common axis within said housing, a cylindrical armature member positioned with said coil members and reciprocable along said axis, a cylindrical coil form member within which said armature member reciprocates having inserts of non-magnetic material positioned between said armature and said coil members and constituting a liquid-tight seal between its interior and said coil members, and an annular permanent magnet positioned concentrically with respect to said armature and between said coil members, said magnet being magnetized radially, said coils being polarized with respect to said magnet such that energization of either of said coil members tend to produce a flux path aiding that produced by said permanent magnet, whereby upon energization of either of said coil members said armature

is moved in a direction to abut against the pole piece nearest said coil member, and upon subsequent de-energizing of said coil member said armature is held in position against said pole piece by the magnetic force produced by said permanent magnet.

3. A solenoid device comprising a substantially cylindrical housing of magnetic material having a pair of pole faces positioned along the axis thereof, a coil of wire positioned within said housing adjacent each of said pole faces, an annular radially magnetized permanent magnet positioned in said housing between said coils of wire, an armature member positioned along said axis and adapted to reciprocate between said pole faces, and a cylindrical structure within which said armature is adapted to reciprocate including a portion of non-magnetic material positioned adjacent each of said coils for blocking a magnetic flux path tending to flow axially through said cylindrical member and causing said flux path to flow through said armature member, said cylindrical structure comprising a liquid-tight seal between its interior and said coils, whereby upon energization of either of said coils said armature is moved in a direction to abut against the pole piece nearest said coil, and upon subsequent de-energizing of said coils of wire said armature is held in position against said pole piece by the magnetic force produced by said permanent magnet.

4. A solenoid comprising a cylindrical armature member, a unitary cylindrical coil form member sealed at one end within which said armature reciprocates having annular inserts of non-magnetic material concentrically positioned with respect to said armature member, an annular coil positioned concentrically with respect to each of said annular inserts, an annular radially magnetized permanent magnet positioned between said coils, a housing of magnetic material enclosing said armature member, coil form member, coils, and magnet having pole faces adapted to engage said armature at each end of its travel, and means for energizing one or the other of said coils, whereby upon energization of either of said coils said armature is moved in a direction to abut against the pole piece nearest said coil, and upon subsequent de-energizing of said coils of wire said armature is held in position against said pole piece by the magnetic force produced by said permanent magnet.

5. A solenoid device as set forth in claim 4, wherein said coils are polarized such that the magnetic lines of force produced upon energization of either of said coils of wire always tends to further magnetize said permanent magnet.

6. A solenoid device comprising a housing a magnetic material having a pair of pole faces, an annular radially magnetized permanent magnet positioned within said housing, an armature adapted for linear movement along the axis of said magnet between said pole faces, a first coil of wire inductively related to said armature, magnet, and housing including one of said pole faces, a second coil of wire inductively related to said armature, magnet, and housing including the other of said pole faces, said coils and said permanent magnet being polarized such that the magnetic lines of force produced upon energization of either of said coils of wire always tends to further magnetize said permanent magnet, and means for energizing one or the other of said coils of wire whereby said armature is caused to abut against the corresponding pole face and will be held against said pole face by the magnetic force produced by said permanent magnet after said coil is deenergized.

7. A solenoid device as set forth in claim 6 wherein resilient means are provided between said armature and one of said pole faces effective to bias said armature toward one of said pole faces.

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