

[54] **SOLENOID OPERATED PLUNGER  
DEVICE**

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[58] Field of Search.....335/229, 230, 234,  
335/253, 254

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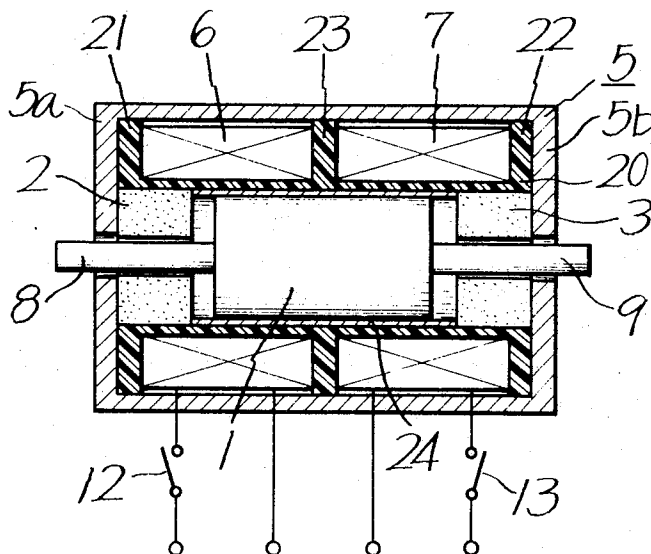
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[57] **ABSTRACT**

Within a cylindrical yoke of magnetic material are disposed first and second axially spaced coils in concentric relationship therewith. A first permanent magnet is arranged inside the first coil in abutting relation with one of the end plates of the yoke, and a second permanent magnet is arranged inside the second coil in abutting relation with the other end plate. A movable magnetic body is located inside the first and second coils for movement between the first and second permanent magnets. A plunger extends from one end of the movable magnetic body through a permanent magnet and the yoke to the exterior thereof. A current pulse supplied to the first coil causes the movable body to be attracted to the first permanent magnet, and a current pulse supplied to the second coil causes the movable body to be attracted to the second permanent magnet.

**6 Claims, 6 Drawing Figures**



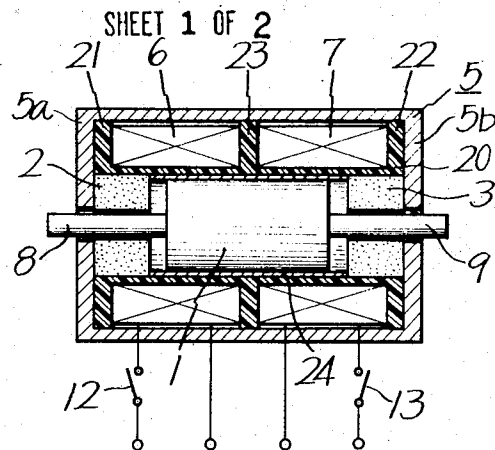


**Fig. 1**

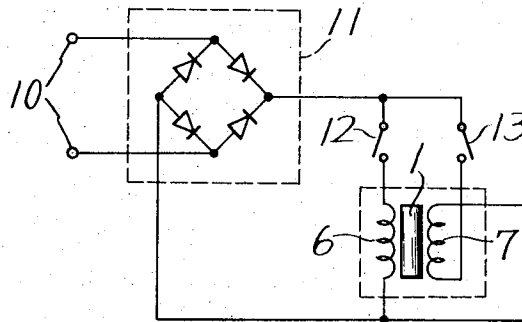


**Fig. 2**

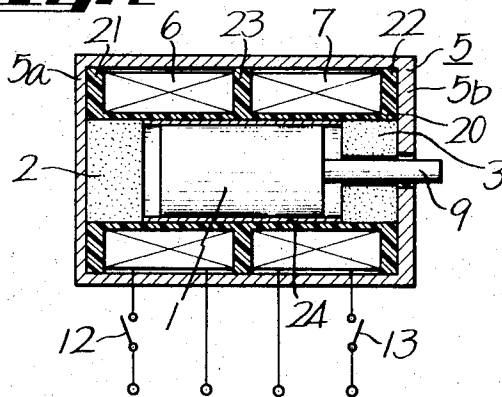


**Fig. 4**

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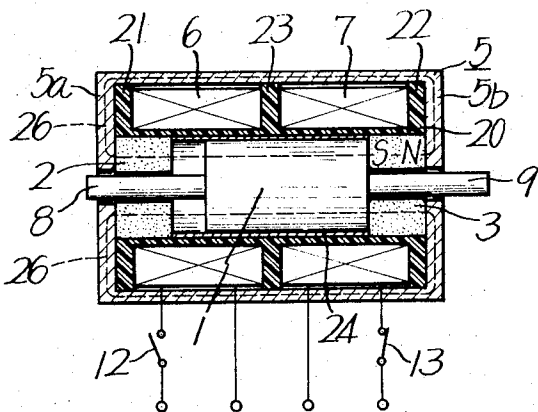


**Fig. 3A**

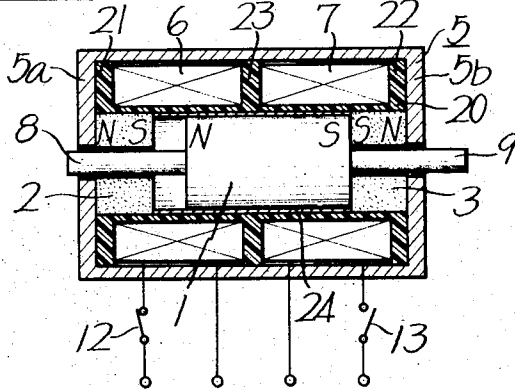


**Fig. 3B**

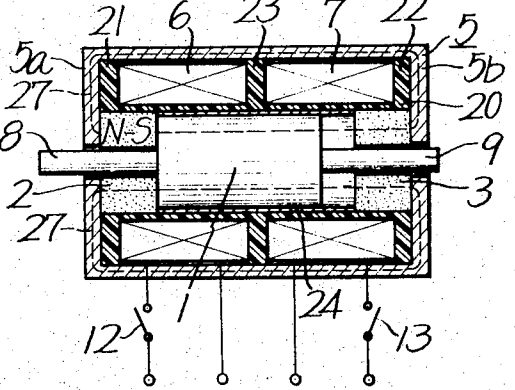


**Fig. 3C**

## SOLENOID OPERATED PLUNGER DEVICE

### BACKGROUND OF THE INVENTION

The invention relates to a solenoid operated plunger device in which current flow through a solenoid coil controls the movement of a plunger, and in particular, to such device which maintains the operated position of the plunger even after the current flow has been interrupted.

Solenoid operated plunger devices of the kind described are known which have the capability to maintain the device in its operated position after the current applied for its operation has been interrupted. However, such prior art devices of holding type either required a relatively high drive current or required a complex driving circuit because of the necessity to supply two currents separately, i.e. one to demagnetize the magnet for holding the device in one state, and the other to magnetize the magnet for holding the device in the other state.

Therefore, it is an object of the invention to provide a solenoid operated plunger device of holding type which operates with a low drive current and incorporates a simple drive circuit.

It is another object of the invention to provide a solenoid operated plunger device of the holding type in which magnetic circuits for producing attraction to move a plunger are common to those for magnetizing and demagnetizing first and second permanent magnets which hold the plunger in a first operating position and in a second operating position, respectively.

### SUMMARY OF THE INVENTION

In accordance with the invention, first and second permanent magnets are arranged on opposite sides of, and spaced from, a movable magnetic body in alignment with the direction of movement thereof. A magnetic yoke is provided to connect these permanent magnets to each other. Along the outer periphery of the movable body and magnets are disposed solenoid coils, each extending across one or the other of the permanent magnet and the movable body. When a current is passed through one of the coils, there is formed a magnetic circuit which extends through the movable body, one of the permanent magnets, the magnetic yoke and the other permanent magnet. The magnetizing force of the magnetic circuit thus formed magnetizes one of the magnets to cause it to attract the movable magnetic body, and also demagnetizes the other magnet. The movable body moves toward the magnetized magnet and is held in position by the latter.

Above and other objects, features and advantages of the invention will become more apparent from the following description of embodiments thereof when taken with reference to the drawings.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic section of an embodiment of the solenoid operated plunger device according to the invention,

FIG. 2 is a circuit diagram of an energizing circuit for the coils shown in FIG. 1,

FIGS. 3A to 3C are similar views to FIG. 1, but illustrating the device in several different positions, and

FIG. 4 is a diagrammatic section of another embodiment of the solenoid operated plunger device according to the invention.

### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, there is shown a movable magnetic body 1 or core which is arranged for movement lengthwise or horizontally as viewed in the drawing. First and second permanent magnets 2 and 3 are disposed spaced from the movable body 1 on opposite sides thereof and in alignment with the direction of movement thereof. A magnetic yoke 5 is provided to connect the outer sides of the permanent magnets 2 and 3. Within the yoke 5 are disposed a pair of coils 6 and 7, these coils being wound around and extending between the movable body 1 and the magnet 2 or 3, respectively. Thus the magnetic yoke 5 is in the form of a hollow cylinder with its opposite ends closed, and a bobbin 20 is arranged within the yoke 5. The bobbin 20 is formed of a synthetic resin material and is integrally formed with flanges 21, 22 and 23 at its opposite ends and at its median. The bobbin 20 has its opposite ends in contact with end plates 5a and 5b of the magnetic yoke 5 and has its flanges 21, 22 and 23 peripherally extending close to the inner periphery of the yoke 5. The coil 6 is wound on the bobbin 20 intermediate the flanges 21 and 23, and the coil 7 is wound on the bobbin 20 intermediate the flanges 22 and 23. Fitted into the opposite ends of the bobbin 20 are the magnets 2 and 3 with a thin-walled cylindrical spacer 24 interposed between the bobbin and the magnets and extending between the magnets 2 and 3 to maintain a given spacing between them. The movable magnetic body 1 of solid cylindrical form is concentrically disposed within the spacer 24 for movement between the magnets 2 and 3.

In the example shown, plungers 8 and 9 of nonmagnetic material extend from the opposite ends of the movable body 1 and project through the magnets 2, 3 and the yoke 5 externally thereof. The direction of winding of the coils 6 and 7 and the polarity of drive currents supplied to these coils are chosen such that the magnetizing force resulting from excitation of either coil 6 and 7 provide opposite magnetic excitations of the magnets 2 and 3. To this end, the drive circuit comprises a rectifier circuit 11 connected to commercial power supply terminals 10, for example, as shown in FIG. 2, with the output terminals of the rectifier circuit being connected across the coils 6 and 7 through switches 12 and 13, respectively. In the arrangement shown, it is assumed that the both coils 6 and 7 are wound in the same direction, and hence they are connected to the opposite polarities of the supply current as shown. The magnets 2 and 3 are formed of a magnetic material which can relatively easily be magnetized and demagnetized.

In operation, assuming that the switch 13 is closed to energize the coil 7 in the position illustrated in FIG. 1, the magnet 3 will be magnetized in a direction such that an end plate 5b of the yoke 5 will be an N-pole, and the magnetizing force furnished by the coil 7 will cause the movable magnetic body 1 to be attracted to the magnet 3, thereby assuming its position shown in FIG. 3A. At this time, the magnetic flux passes through a magnetic

circuit, indicated by dotted lines 26, which includes the yoke 5, magnet 2, movable body 1 and magnet 3. If now the switch 13 is opened to interrupt the energization of the coil 7, the magnet 3 remains magnetized, so that the movable body 1 is held in position as attracted thereto.

If then it is desired to move the movable body 1 toward the magnet 2, it is only necessary to close the switch 12. Then the coil 6 produces a magnetizing force which will cause the magnet 2 to be magnetized so that the end plate 5a of the yoke 5 will be an N-pole, or in a direction opposite to that of previous magnetization of the magnet 3. Now the magnetizing force is effective to magnetize the movable body 1 with a polarity opposite to that of previous magnetization of the magnet 3, so that the movable body 1 is repelled by the latter, which is demagnetized. The force of attraction by the magnet 2 acts simultaneously to cause the movable body 1 to be attracted to the magnet 2, thereby causing it to assume a second position shown in FIG. 3C. The magnetic flux passes through a magnetic circuit indicated by dotted lines 27, which again includes the yoke 5, the both magnets 2 and 3, and the movable body 1. A similar process may be repeated by closing the switch 13 again, which will cause the magnet 2 to be demagnetized and the magnet 3 to be magnetized as shown in FIG. 3A, thereby achieving a position of the movable body 1 as shown in FIG. 3A.

Thus, the solenoid operated plunger device of the invention enables a movable magnetic body to be moved from one position to another by a momentary application of current upon operation of the device, and still holds the movable body in position which it now assumed, subsequent to interruption of the current, thus avoiding further power dissipation. When a drive current is supplied to one of the coils, the resulting magnetizing force causes a magnetization of one of the magnets and also an attraction thereto of the movable body, but immediately before that, causes a demagnetization of the other magnet which has been retaining the movable body. Thus such magnetization, attraction and demagnetization are all provided by the magnetizing force occurring in the same magnetic circuit which includes the movable body 1, both magnets 2 and 3 and magnetic yoke 5, and this minimizes the drive current required. The drive circuit does not require separate coils for demagnetization and magnetization, respectively, and hence is extremely simple. In addition to maintaining a given spacing between the magnets 2 and 3, the spacer 24 is also effective to prevent abrasion which may otherwise be caused to surrounding parts by sliding motion of the movable body 1.

While in the above description plungers have been provided on opposite sides of the movable body, one of the plungers may be omitted as shown in FIG. 4 in which corresponding parts are designated by like numerals.

A practical example was constructed according to the embodiment of FIG. 1. Movable body 1 comprised a piece of soft iron of 16.5 mm in diameter and 36 mm long. Magnets 2 and 3 comprised Alnico with an outer diameter of 18.0 mm, an inner diameter of 4 mm and an axial thickness of 10 mm. Magnetic yoke 5 was formed of iron material designated as SS 34 in JIS (Japan Industrial Standard), measuring 40.0 mm and

36.0 mm in outer and inner diameters, respectively, 65.0 mm long and having a thickness of 3.0 mm for end plates 5a and 5b. Coils 6 and 7 each comprised 2,200 turns of wire of 0.13 mm  $\phi$  and had a d.c. resistance of 74 ohms, plungers 8 and 9 were each a copper rod of 3 mm in diameter. Bobbin 20 was formed of polyacetal synthetic resin in the form of a hollow cylinder having an outer and inner diameter of 20.2 mm and 18.0 mm, respectively, integrally formed with flanges 21, 22 and 23. Spacer 24 was a cylindrical copper pipe having an inner diameter of 17.0 mm, an outer diameter of 18.0 mm and a length of 39.0 mm. When one of the switches 12 and 13 was closed to supply rectified current from a commercial power supply of 100 volts for 50 milliseconds, the movable body 1 switched in position, moving into contact with one of the magnets with a force of 3.5 kilograms. After interruption of current supply, the movable body 1 was held in position with a retaining force of 5 kilograms. The device exhibited an excellent life response as evidence by more than 100,000 times of reciprocatory motion of the movable body 1.

While the invention has been described with reference to particular embodiments, it should be understood that many modifications will occur to those skilled in the art without departing from the scope and spirit of the invention as defined by the appended claims.

What is claimed is:

1. Solenoid operated plunger device comprising first and second permanent magnets disposed on opposite sides of a movable magnetic body and spaced therefrom in alignment with the direction of movement thereof, a magnetic yoke disposed externally of the magnets and connecting them to each other, a first solenoid coil within the yoke and extending across the first magnet and the movable magnetic body at a position external of both, a second solenoid coil within the yoke and extending across the second magnet and the movable magnetic body at a position external of both, and a plunger mounted on at least one end of the movable magnetic body and extending through an associated one of the magnets and the yoke to the exterior thereof, said permanent magnets, movable magnetic body, coils, and magnetic yoke being so disposed relative to one another that the flux path of the first permanent magnet, the flux path of the second permanent magnet, the path of flux produced upon energization of the first coil, and the path of flux produced upon energization of the second coil all extend in common along a single magnetic path which passes in succession from one of said permanent magnets through said movable body, then through the other of said permanent magnets, and then through said magnetic yoke to said one of said permanent magnets, said movable magnetic body being moved from a position where it is held attracted to one of the permanent magnets to a position adjacent the other permanent magnet by so energizing the coil associated with said other permanent magnet as to produce a flux which cancels the flux from said one permanent magnet and which demagnetizes said one permanent magnet.

2. Solenoid operated plunger device comprising a cylindrical magnetic yoke having its opposite ends closed, a first coil concentrically disposed within the

yoke and along the inner periphery thereof within substantially one-half of the axial length of the yoke, a second coil concentrically disposed within the other half of the yoke and along the inner periphery thereof, a first permanent magnet located inside the first coil in contact with one of the end plates of the yoke, a second permanent magnet located inside the second coil in contact with the other end plate of the yoke, a movable magnetic body arranged for movement within the first and second coils between the first and second magnets, and a plunger mounted on one end of the movable magnetic body and extending through the first permanent magnet and one of the end plates to the exterior thereof, the space between said first and second coils being constituted entirely by non-magnetic material, whereby the energization of either of said coils produces a flux which passes through both of said permanent magnets, through said movable magnetic body and through said yoke without extending into the space between said first and second coils.

3. Solenoid operated plunger device according to claim 2 further including means for supplying the first and second coils with a drive current separately, and wherein the direction of winding of the first and second coils and the polarity of the drive current are chosen such that the direction of magnetization of the first and

second magnets caused by a current supplied to the first coil is opposite to the direction of magnetization of the first and second magnets caused by a current supplied to the second coil.

4. Solenoid operated plunger device according to claim 2, further including a second plunger mounted on the other end of the movable magnetic body and extending through the second magnet and the other end plate to the exterior thereof.

5. Solenoid operated plunger device according to claim 2, in which the magnetic yoke is in the form of a hollow cylinder and has a bobbin concentrically disposed therein, the first and second coils being wound on one-half and the other half of the bobbin, respectively, the first and second magnets being fitted into the opposite ends of the bobbin, the movable magnetic body being arranged within the bobbin for movement between the first and second magnets.

6. Solenoid operated plunger device according to claim 5, further including cylindrical spacer means of nonmagnetic material interposed between the inner periphery of the bobbin and the magnets for maintaining a given spacing between the first and second magnets, the movable magnetic body being arranged within the spacer means for axial movement therein.

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